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OF
CIVIL ENGINEERS



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BOSTON SOCIETY OF CIVIL ENGINEERS
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PROCEEDINGS

NOTICE OF REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on

WEDNESDAY, MAY 17, 1916,

at 8 o'clock P.M., in CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Mr. Thomas C. Atwood will present a paper entitled, "The Yale Bowl." The paper will be illustrated with lantern slides.

S. E. TINKHAM, *Secretary*.

PAPERS IN THIS NUMBER.

"The Dorchester Tunnel," A. A. Cohill.

"Reconstruction of the Cambridge, Ohio, Water Works,"
W. J. Sherman.

"Weight of Stone in Vessels," A. S. Ackerman.

"Slide Rules for Concrete Design," E. F. Rockwood.

Discussion of "Sand and Oil Roads."

Memoir of Deceased Member.

CURRENT DISCUSSIONS.

Paper.	Author.	Published.	Discussion Closes.
"Spillways of Panama Canal."	E. C. Sherman.	April.	Aug. 10.
"Latest Method of Sewage Disposal."	E. Barton.	April.	Aug. 10.
"Service for the Society."	E. M. Blake.	April.	Aug. 10.

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Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

MINUTES OF MEETING.

BOSTON, April 21, 1916. — A regular meeting of the Boston Society of Civil Engineers was held this evening in the Assembly Room of the Engineers Club, and was called to order at 8 o'clock by the President, Richard A. Hale.

There were 82 members and guests present, including a number of members of the Boston Section of the American Institute of Electrical Engineers and of the American Society of Mechanical Engineers, who had been invited to join in the meeting.

By vote, the record of the annual meeting as printed in the April JOURNAL was approved.

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named:

Members — Thomas Allen Appleton, Selden John Gulesian and John T. Scully.

Junior — Samuel Morrison Ellsworth.

Mr. Joseph S. Craigue, a former member of the Society, had been reinstated to membership.

The Secretary also announced that the Board, under authority of a vote passed at the annual meeting, had appointed the following committees of the Society:

On the Library — S. Everett Tinkham, chairman; Henry F. Bryant, Frederic I. Winslow.

On Publication — Charles W. Sherman, chairman; George A. Carpenter, DeWitt C. Webb, George C. Whipple, Sanford E. Thompson, Arthur W. Dean.

On Membership — Charles R. Gow, chairman; Burtis S. Brown, Edward F. Rockwood.

On Papers and Program — Richard A. Hale, chairman *ex officio*; Lewis E. Moore, Sturgis H. Thorndike, Edmund M.

Blake, Edward H. Rockwell, George E. Russell, Robert Spurr Weston, Charles B. Breed, S. Everett Tinkham.

On Social Activities — Henry A. Symonds, chairman; David A. Ambrose, Edwin R. Olin, Charles H. Eglee, Alfred E. Burton, Dana M. Wood, George A. Sampson.

The report of the Board of Government on Permanent Bench Marks about Boston, printed in the April JOURNAL, was then considered, and on motion of Mr. Gow it was voted to refer the matter back to the Board with full power to appoint a member to represent the Society on the committee suggested, should the Board deem it advisable.

The Secretary presented a memoir of John H. Gerrish, an associate of the Society, prepared by a committee consisting of Frank W. Hodgdon and John L. Howard. By vote, the memoir was accepted and ordered printed in the JOURNAL.

The President then introduced Dr. Alexander C. Humphreys, president of the Stevens Institute of Technology and a past president of the American Society of Mechanical Engineers, who read a carefully prepared paper entitled, "Reform and Regulation." The paper considered the question of reform in the regulation of public-service utilities.

The paper was discussed by Prof. D. C. Jackson and Past President Frederic P. Stearns of the Society, and by the Hon. Alonzo R. Weed, chairman of the Board of Gas and Electric Light Commissioners of Massachusetts. A discussion prepared by Mr. J. Parker Snow was also presented, but on account of the lateness of the hour was not read. It will be printed, however, in the JOURNAL.

The thanks of the Society were extended by a rising vote to Dr. Humphreys, for his kindness in presenting his valued paper.
Adjourned.

S. E. TINKHAM, *Secretary*.

EMPLOYMENT BUREAU.

THE Board of Government maintains an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society rooms two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

MEN AVAILABLE.

354. Age 22. Graduate of Malden High School, scientific course, 1913, and of Lowell Inst., structural course, 1915. Has had over two years' experience, including work as time, stock and cost data clerk on Commonwealth Pier, and as rodman and instrumentman on survey for railway valuation department. Desires position along civil or mechanical lines. Will accept position at \$50 per month, if permanent and with chance to advance.

355. Age 25. Received technical education at Thayer School of Civil Engineering, Dartmouth College. Has had two and one-half years' experience in municipal work, including drafting, transit work, and inspecting. Salary desired, \$75 per month.

356. Age 22. Student for three years at Mass. Inst. of Technology; has taken work at summer surveying camp. Has had eight months' experience as rodman, draftsman and transitman with civil engineer; also one fall and winter's experience as draftsman and assistant engr. with underground department of Bay State St. Ry. Desires position for summer as chief-of-party or assistant engr.; will be available June 19. Salary desired, \$20 per week.

357. Age 20. Student for three years at Tufts College Engineering School. Has had three months' experience as chainman, levelman and transitman and in general office work. Desires position as rodman, levelman or transitman. Salary desired, \$15 per week.

358. Age 32. Received technical education at Mass. Inst. of Technology. Has had experience as follows: two years on municipal improvements, water works, sewerage, etc.; two years in consulting engineer's office, on investigations and reports, water-power development, water supplies, etc.; seven years as contracting engineer and superintendent, on steel, brick, concrete — plain and reinforced — cofferdams, etc.; has also had experience as executive, in buying, etc. Is open to any reasonable offer.

LIST OF MEMBERS.

ADDITIONS.

BREEN, CHARLES H.....131 State House, Boston, Mass.
 GULESIAN, SELDEN J.10 Mechanic St., Boston, Mass.
 SCULLY, JOHN T.....185 Devonshire St., Boston, Mass.

CHANGES OF ADDRESS.

DOTTEN, WILLIAM J.520 Medford St., Malden, Mass.
 GRAY, THOMAS F.Tufts College, Mass.
 MANN, OSWELL F.26 Bartlett St., Somerville, Mass.
 MCCORKINDALE, RALPH I.Box 108, New Bedford, Mass.
 REED, LESLIE P.

With Bay State Dredging and Contracting Company, Charles River, Mass.
 ROUNTENBERG, HENRY W.P. O. Box 24, Richardson Park, Del.
 SPALDING, FREDERIC P.....204 Alford St., Charlestown, Mass.
 WENTWORTH, JOHN P.....66 Sprague St., Malden, Mass.
 WHITMORE, HAROLD C.91 Baker St., Lynn, Mass.

DEATH.

ROSS, CHARLES W.April 11, 1916.

RESIGNATIONS.

(In effect March 15, 1916.)

BEOLA, PABLO	DALTON, MARSHALL
BLOOD, JOHN BALCH	OAKES, JOHN J.
CURTIS, LOUVILLE	WILEY, WALTER T.

LIBRARY NOTES.**RECENT ADDITIONS TO THE LIBRARY.****U. S. Government Reports.**

Evaporation of Brine from Searles Lake, California. W. B. Hicks.

Comparative Financial Statistics of Cities under Council and Commission Government, 1913 and 1915.

Geology and Oil Prospects of Cuyama Valley, California. Walter A. English.

Mineral Resources of United States, 1914, 2 vols. Part I, Metals; Part II, Non-metals.

Reconnaissance for Phosphate in Salt River Range, Wyoming. G. R. Mansfield.

Notes on Promontory District, Utah. B. S. Butler and V. C. Heikes.

Methods for Determination of Physical Properties of Road-Building Rock. Frank H. Jackson.

Relation of Mineral Composition and Rock Structure to Physical Properties of Road Materials. E. C. E. Lord.

Water-Supply Papers 369 and 375-G.

Care and Improvement of the Wood Lot. C. R. Tillotson.

State Reports.

Maine. Annual Report of Public Utilities Commission for 1915, Vol. 1.

New Jersey. Annual Report of Commissioner of Public Roads for 1915.

New York. Annual Report of Public Service Commission for First District for 1913, Vol. 1.

Municipal Reports.

Brookline, Mass. Annual Report of Water Board for 1915.

Fall River, Mass. Annual Report of Watuppa Water Board for 1915.

Leominster, Mass. Annual Report of Water Board for 1915.

Milwaukee, Wis. Annual Reports of Sewerage Commission for 1914 and 1915.

Newton, Mass. Annual Report of Water Commissioner for 1914.

North Adams, Mass. Annual Reports of City Officers for 1915.

North Adams, Mass. Annual Report of Department of Public Works for 1915.

Northampton, Mass. Annual Report of Water Commissioners for 1915.

Plymouth, Mass. Annual Report of Water Commissioners for 1915.

Springfield, Mass. Annual Report of Water Commissioners for 1915.

Springfield, Mass. Office Reference Pamphlet, 1915.

Miscellaneous.

L'Asie Mineure et les Turcs en 1875. Auguste Choisy.

Canals of Canada. Thomas C. Keefer.

Ice Floods and Winter Navigation of Lower St. Lawrence. Thomas C. Keefer.

Alois von Negrelli, Vol. 1. Alfred Birk.

Philosophy of Railroads. Thomas C. Keefer.

(Above five items gift of Clemens Herschel.)

International Engineering Congress, 1915: Transactions, 2 vols.: Electrical Engineering and Hydro-electric Power Development; Municipal Engineering.

Case against Municipal Ownership. F. G. R. Gordon.

Rensselaer Polytechnic Institute: Electrical Resistances and Temperature Coefficients of Nickel-Copper-Chromium Alloys. Frederick M. Sebast.

Wood-using Industries of Indiana. J. C. Nellis.

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before the first of each month.)

Commonwealth of Massachusetts.—METROPOLITAN WATER AND SEWERAGE BOARD. — *Water Works.*

Sudbury Power Plant. — The work of installing the hydro-electric machinery at the Sudbury Dam in Southboro is in progress.

Sewerage Works. — Work is in progress on Sections 103 and 104, Wellesley extension; and on the Malden River Siphon. The contract for the Deer Island extension of the outfall sewer has been let. Further work on the Wellesley extension sewer is contemplated.

METROPOLITAN PARK COMMISSION. — The following work is in progress:

Alewife Brook Parkway. — Surfacing and finishing Alewife Brook Parkway, from Massachusetts Ave. to Powder House Boulevard. Kelley & Sullivan, contractors.

Charles River Reservation. — Building reinforced concrete bridge over the Charles River at North Beacon St., Boston and Watertown. A. G. Tomasello, contractor.

The construction of a reinforced concrete bridge over the Charles River at Commonwealth Ave., Newton and Weston, will be begun soon.

Work of excavating channel of Charles River from Elm St. to Bleachery Dam, Waltham, is in progress. John R. Burke, contractor.

Furnace Brook Parkway. — The construction of parkway extension from Quincy Shore Reservation to Hancock St. John Cashman & Sons Company, contractors.

Building reinforced concrete girder bridge across Blacks Creek, for Furnace Brook Parkway Extension. Hugh Nawn Contracting Company, contractors.

Mystic Valley Parkway. — Excavation of the channel of Aberjona River from Boston & Maine Railroad Bridge to Waterfield St., Winchester. Coleman Brothers, contractors.

Old Colony Parkway. — Plans are being prepared for bridge over the Neponset River, Boston and Quincy, to replace old wooden bridge.

DIRECTORS OF THE PORT OF BOSTON. — *Reclamation of State Flats at East Boston.* — Under the contract with the Bay State Dredging and Contracting Company, further progress has been made in the construction of the 2 200 lin. ft. of bulkhead and filling adjacent thereto. The contract for rehandling 1 000 000 cu. yds. of material and depositing the same on flats east of Jeffries Point to reclaim 35 acres was awarded to the Atlantic, Gulf & Pacific Company on March 14, 1916. Pile ranges showing the limit of this work have been placed and active dredging is expected to commence at an early date.

Dry-Dock at South Boston. — Further progress has been made in the work at the dry-dock under the contract with the Holbrook, Cabot & Rollins Corporation. The dredging over the dry-dock site has been completed, with a total of about 290 000 cu. yds. removed.

The cofferdam being built across the open end of the site consists of two rows of 6-in. sheeting, eight feet apart, and double rows of piles. The space between the sheeting will be filled with clay, and embankments placed on both sides of the sheeting. When completed, this cofferdam will permit of unwatering the site and the excavation in the dry of the earth and rock for the dock walls and floor.

The contractor has continued the assembly of plant, the erection of cableway towers, and of materials for the dry-dock.

Extension of Northern Avenue. — Bids were received by the Directors on April 14, 1916, for the construction of 1 000 lin. ft. of timber bulkhead for the extension of Northern Ave. from its present terminus near the fish pier toward the dry-dock. The lowest bid was that of William H. Ellis & Son Co., which was \$23.61 per lin. ft. of bulkhead, and the contract was awarded to him on April 17, 1916. The area enclosed by this bulkhead will be filled with cinders and ashes and other material suitable as a foundation for the roadway.

Sewer in Fargo Street. — Further progress has been made in

the contract for construction of the sewer in Fargo St. between C and D Sts., to connect with the sewer of the city of Boston at C St.

Tide Gage. — An automatic tide gage has been purchased and installed by the Directors at Commonwealth Pier 5, South Boston, to maintain a systematic record of tidal fluctuations. This gage is of the 8-day type and arranged to record a tidal fluctuation of 20 ft. upon a chart having graduations of one-half inch per foot of tidal fluctuation, and one-half inch for each hour of time. It is expected that this gage will furnish valuable information not only to shippers but in all engineering work connected with the harbor improvements.

Wollaston Yacht Club Channel. — The dredging of the channel to the Wollaston Yacht Club has continued, and to date about 70 000 cu. yds. of material have been removed. This channel will have a width of 70 ft. and a depth of 8 ft. when completed.

Neponset River Dredging. — The work under a contract with the Gerrish Dredging Company for dredging about 35 000 cu. yds. of material from the Neponset River near Milton Lower Mills was begun on April 18, 1916. The depth to be obtained is 6 ft. at mean low water.

Boston Transit Commission. — *Dorchester Tunnel.* — Descriptions of Sections D, E, G and H were printed in the JOURNAL in October and December, 1915.

In Section E both shields are under the channel, the one for the easterly tunnel being within about 300 ft. and the one for the westerly tunnel within about 600 ft. of the northerly end of the section, where they will meet the completed tunnel at the easterly end of Section D under Summer St. About four fifths of the construction of Section E is done.

Section F includes a two-story underground station in Dorchester Ave., between Broadway and West Fourth St. The lower level is for the Dorchester Ave. trains, and the upper level for surface cars which will enter and leave by inclines, one in Dorchester Ave. just south of West Fourth St., and the other opening in Foundry St. between Broadway Extension and Dor-

chester Ave. This combined station for trains and surface cars allows passengers to transfer by means of stairs from one level to the other underground. The T. A. Gillespie Co. is the contractor for this section, and work is now in progress.

On Section G the sewer changes are being made. The construction of the tunnel structure in open cut between West Fourth and B Sts. in Dorchester Ave. is in progress.

The contract for the construction of Section J of the Dorchester Tunnel, which is located in and near Dorchester Ave. and Boston St., and includes the Andrew Square Station, has been awarded to The T. A. Gillespie Company, and work has been started near Dexter St.

City of Boston. — PUBLIC WORKS DEPARTMENT, HIGHWAY DIVISION, PAVING SERVICE. — Work is in progress on the following streets:

Dunlap St.,	Washington St. to Whitfield St.	Asphalt.
Jones Ave.,	Mascot St. to Ballou Ave.	Asphalt.
Kittredge St.,	Cornell St. to Beech St.	Bitulithic.
Public Alley No. 903,	Haviland St. to Public Alley No. 904.	Hassam block.
Public Alley No. 904,	Bickerstaff St. to Public Alley No. 903.	Hassam block.
Rosewood St.,	Oakland St. to Randolph St.	Asphalt.
Spring St. (fence) at West	Dept., City Hospital.	
Sturtevant St.,	Park St. to Gibson St.	Hassam block.
Wachusett St.,	Weid Hill St. to Barlow St.	Excavating and grading.

The Fore River Shipbuilding Co., Quincy, Mass., has the following work in progress:

- Seventeen submarine boats for U. S. Navy.
- One submarine for Spanish Navy.
- One oil tanker for Argentine Government.
- Two torpedo boat destroyers, Nos. 63 and 64.
- Four oil boats for the Texas Co.
- Three molasses steamers for the Cuba Distilling Co.
- Five freight steamers for the Luckenbach Co., Inc.
- Two steel tank steamships for the Petroleum Products Co.

BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

**THE CONSTRUCTION OF THE DORCHESTER
TUNNELS UNDER FORT POINT CHANNEL.**

By A. A. COHILL.*

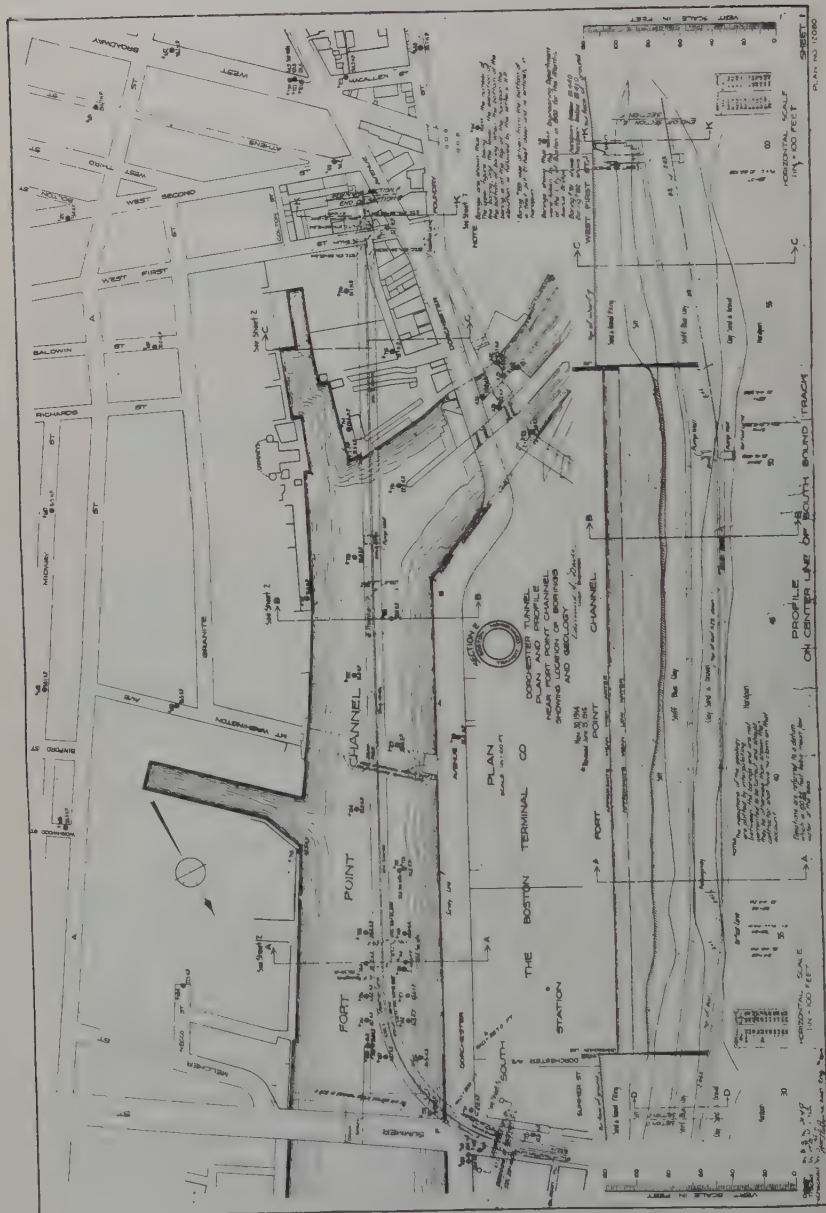
(Presented December 15, 1915.)

IN presenting this paper on the construction of the Dorchester Tunnels under Fort Point Channel, I shall begin with the shaft upon which work was started on January 6 of this year by Patrick McGovern & Co., contractors for the work. This shaft is located on First Street, near Dorchester Avenue, South Boston. The tunnels are being driven in a northerly direction beneath the body of water known as Fort Point Channel to a point where they join with subway work just completed by the Hugh Nawn Contracting Company near the side entrance to South Station, Summer Street, Boston.

The shield, which is of the circular type with an outside diameter of 24 ft., has twenty-four hydraulic jacks, with eight additional jacks for table movement upon which a light pressure is maintained at all times, causing the platforms to move forward and support the breast or heading. The twenty-four hydraulic jacks are located in the tail of the shield and they engage the completed tunnel in such a manner that when the hydraulic

NOTE. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before August 10, 1916, for publication in a subsequent number of the JOURNAL.

* Chief Engineer, P. McGovern & Co., Boston.



pressure is applied, the shield is moved forward a distance of 30 in., which is termed "a shove," and the building in of two sets of wood segments, or, in other words, two rings, is permitted. The maximum pressure in the jacks is 5 000 lbs. and the average 3 500 lbs. to the square inch, or 75 tons to the jack. It requires sixteen segments and one short block, which is called a key, to build a ring. The segments are something over 4 ft. in length,



DORCHESTER TUNNEL, SECTION E. SHIELD AND WOOD TUNNEL LINING.

and square about 10 in. They are held in place by steel pins forced into them by the shield jacks. We get about nine shoves every twenty-four hours, the excavation, of course, being carried on from the various decks in the shield without interruption.

These tunnels are subaqueous, and, as was anticipated, we found it necessary to put the headings under air pressure when they had reached a point about 200 ft. away from the shaft. The building of the necessary bulkheads and the installation of the locks was quickly done, and the air was first turned into the headings at a pressure of 25 lbs.

Air Locks.

The material locks, two in each tunnel, are interestingly large, being 7.5 ft. in diameter. The man or emergency lock in each tunnel is located directly above the material locks and will conveniently accommodate from thirty-five to forty men. As the work progressed and we became more familiar with the conditions, we lowered the pressure of air to 18 lbs. per sq. in., and later raised it to 20 lbs. when at a point directly under the channel. This is the air pressure now carried.

It might be interesting to you if I should say something about the effect of compressed air upon the workmen. About one of the first things one hears much of are the "bends." I will leave it to the medical fraternity to explain just what is meant by the term "bends." I will say, however, that we have had some of our laborers incapacitated by the effects of the compressed air. This seems to occur more frequently after the pressure has reached a point over 22 lbs., and in nearly every case I investigated, I found the disablement was brought about through some indiscretion on the part of the individual affected. Decompressing too quickly accounts for much of the trouble, and the change of temperature without proper clothing, which is common among the workmen, is bound also to give trouble.

A cross section of the tubes would show the following construction employed. First the wooden ring made up of the long-leaf yellow pine segments and key, then the waterproofing of three-ply Minwax cloth well mopped with hot asphaltum, then the inner lining of concrete at a minimum thickness of 2 ft.

After the shield has been moved forward and the rings placed, there is a space between the material through which the shield is passing, and the outer skin of the tunnel. This space is filled with a mixture of sand and cement ejected through holes bored in the wooden lining. We have been using a pressure of about 45 lbs. for the ejection of this grout.

The concrete arch and side walls are molded with steel forms made up of plates and angles in sections of 15 ft. with plate subsections of 5 ft. each. These subsection plates can be removed so that the concrete may be placed behind the forms at any desired elevation. One 15-ft. section of the form is trans-

ported by a large gantry or carrier. After this section has been lowered into position, the gantry is collapsed and moved backward through the tunnel, to be used in bringing forward another set of forms. This operation is repeated over and over each twenty-four hours. The rail supporting the carrier is laid along the duct steps on either side of the invert. The work of laying



DORCHESTER TUNNEL, SECTION E. STEEL FORMS AND TRAVELER,
LOOKING IN FROM SHAFT.

the concrete invert is carried along in advance of the arch and side wall construction.

There are several features in connection with the construction of these tunnels to which I wish to call particular attention. The system as worked out by Mr. McGovern and Mr. Charles R. Gow, the able President of your Society, and consulting engineer for the contractors, allows muck to be handled through all other work to cars in the completed tunnel. It permits the concreting of invert, the waterproofing of both invert and arch, the placing of the wood lining and the concreting of arch. Each one of these

individual operations can be carried along with full crews during each twenty-four hours. The contributing factors to this system are a belt conveyor and a platform which is outrigged from the back of the shield.

This conveyor is about 100 ft. long, and is attached to the shield and moves along as the shield advances. The structure carrying the belt and its appurtenances, as well as the motor and hoppers, is mounted on wheels, which roll along a narrow-gage track that becomes one of the material tracks. To one side of this conveyor the muck cars are placed, and the muck, as shoveled from the different decks of the shield on to the rubber belt is discharged into these cars at a point well back on the completed invert and just forward of the arch and side wall construction.

The platform, which is attached to the shield and from which we do our grouting, place our wooden segments and store all the material to be used in each move, is supported by two H-beams of 15-in., 100-lb. section, with raker rods with turnbuckles for adjustment. The arrangement of this platform permits waterproofing the invert, the grouting and the lining with wood blocks to be carried on simultaneously without interference.

There are several interesting details in connection with the shaft on First Street which are worthy of mention. There are two elevators delivering the tunnel cars to a gantry well above the level of First Street, and without any interference to public travel. When the tunnel cars reach the top of this gantry, they are dumped through hoppers into 4-yd., narrow-gage cars, which are always in waiting, and are in turn hauled over a two-track elevated structure to a terminal dock on Fort Point Channel, where scows come alongside to receive the muck, and to discharge the yellow pine segments used for building the outside skin of the tunnel.

Power House.

The compressing machinery, electrical equipment, machine and blacksmith shop are located here. There are in this plant four boilers each of 150 h.p. capacity, two low-pressure Sullivan compressors, one high-pressure Sullivan and two high-pressure Ingersol-Sargent compressors, two General Electric generators of

50 kw. each, the necessary hydraulic pumps, condensers, etc. The Sullivan compressors have a capacity of about 2 200 cu. ft. of free air per minute.

If you should attempt to follow out the sequence of our work, you would find many little changes and innovations.

The first one I wish to call attention to is the conveyor. We originally had a long ramp or incline, for it was our intention, and for a while we had it in operation, to draw the concrete cars up this incline and along the track over the conveyor belt to the deck of the concrete form carrier. This was not a success, and we very quickly did away with that portion of the conveyor frame. I allude to this to show the trials the contractor is put to in endeavoring to make the plant fit the conditions. To take the place of this ramp or incline, we installed a platform carriage or traveler similar in manner to that which handles the concrete forms, and with it an elevator which is operated by a two-drum hoist run by compressed air. The concrete is brought into the tunnel in $1\frac{1}{2}$ -yd. concrete cars, which are on the forward part of the train as it moves down the tunnel. These cars are delivered to the elevator, hoisted to the deck of the gantry, rolled from that point to the deck of the concrete form carrier and dumped. From this point the concrete is placed behind steel forms.

It was our original intention to have three operating tracks the entire length of the tunnel, giving the center track over to the concrete delivery alone, and allowing the muck cars or a muck train to stand on either side of the conveyor, and then with the aid of a deflection table, discharge the muck on either side. This had to be given up for a lack of clearance between the sides of the invert. While these changes were slight, for a time they had considerable bearing on the progress of the work.

While speaking of progress I would say that our best month's run in one tube was 375 ft. This means 375 ft. of completed tunnel. Our average run for the best three months was 325 ft. per month, a goodly portion of this being in hard pan, which accounts for the slowdown and difference as shown for one month. I think I am safe in saying this establishes a record for subaqueous tunnel driving. Every cubic foot of material in the heading had to be brought through the shield and out of the locks.

When the air pressure was first placed on the tunnels, which was early in June, we did not consider it necessary to make any provisions for cooling the air, but we found this was a problem that would have to be reckoned with, and we were not very long installing after-coolers. There is nothing new about after-coolers, but there are different designs, and I think it might be interesting for you to know something about the cooler we are using. It is about 3 ft. in diameter, and 12 ft. long, with about one hundred and twenty $1\frac{1}{2}$ -in. brass tubes through which harbor water is pumped. As the air leaves the compressor it passes into the after-cooler, where it is expanded and cooled and then carried on to the heading through an 8-in. steel pipe. At the discharge end of this pipe, the air is practically dry. We have experienced no trouble whatever from carbon dioxide. It is safe to say you will find the temperature of the air at the discharge end of the after-cooler about 15 degrees higher than the temperature of the water that is being used to cool it. To-day we had a temperature of 187 degrees at the compressor end of the after-cooler, and a temperature of 65 degrees at the discharge end, with a harbor temperature of 50 degrees. The tunnel temperature was about 72. This difference of 7 degrees might be accounted for by friction produced in the pipe, as well as by a reducer that caused back pressure, and the fact that the temperature readings at the after-cooler were taken in the morning, and the tunnel temperature in the afternoon. For the benefit of those interested in plant installation I will say that the Sullivan compressors which are installed in the power house are all high-pressure machines. Our object in using this type was that for a small expense the inter-coolers could be replaced at any time, and from a standpoint of salvage, these machines could be sold more readily on account of the demand greater for high-pressure than for low-pressure compressors.

Hospital and Hospital Lock.

About the time we placed the air on the tunnels, we installed a hospital lock which is located in the power house. We found it advantageous to have this, and have treated a few cases of "bends." We have a small room fitted up near the shaft, with

a graduate nurse in daily attendance, where accidents of a minor nature are taken care of. We have fitted up a well-lighted, well-heated hog-house, equipped with showers and plenty of locker room, where the men are given hot coffee at any time during the day or night. These quarters are well cared for, as the efficiency of the workmen is a matter of important consideration.

Concrete Mixing Plant.

Just south of First Street, directly alongside of our shaft, we installed the concrete mixing plant; by simply putting in the side walls in that portion of the tunnel we are building south toward Broadway, and leaving out the arch, we took enough available space to install sand bins. The tops of these bins are on the same level as First Street, which permits the motor trucks and teams drawing sand and stone to dump their loads directly into the bins. At a point sufficiently high above the tunnel invert to permit a concrete car being pushed under it, the concrete mixer is located. The cement shed is also located on a level with First Street, and the cement in bags is passed down to the mixer through a spiral chute. This gives us a gravity mixing plant which is operated very economically.

The material encountered in the heading up to the present consists chiefly of clay, with an occasional streak of sand. This clay stands up well under 20 lbs. pressure of air, but without the air it flows freely. We have just begun to encounter a mixture of sand, gravel and clay (hardpan) and now and then a boulder. This underlies the clay and is gradually rising in the face of the shield. We have found it advantageous at times to use explosives, employing very light charges of 20 per cent. dynamite. This is loaded in four cut-off holes, directly in front of the bottom cutting edge of the shield, and in four breakdowns just above the first deck of the shield.

The amount of air escaping through the heading up to the present time is *nil*. We are supplying to the two tubes about 1 900 cu. ft. of free air per minute, which is not quite the capacity of one of our large machines. The ventilation is good.

The constant operating of the locks provides the tunnel with

very good circulation. We experience no bad effects whatever from the smoke produced by the dynamite.

Waterproofing.

It was thought at one time that the efficiency of the men might be impaired by the fumes arising from the hot asphaltum which is used in connection with the waterproofing. This was, of course, before we had used any. There has been no time when we have had any trouble from this source.

The work of constructing these tunnels is being done for the Boston Transit Commission, of which George F. Swain is chairman, Edmund S. Davis, chief engineer, and G. D. Emerson, assistant engineer in direct charge of this and adjoining subway sections.

BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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THE RECONSTRUCTION OF THE MUNICIPAL WATER
WORKS, CAMBRIDGE, OHIO.

By W. J. SHERMAN,* M. AM. SOC. C. E.

(Presented before the Sanitary Section, February 2, 1916.)

THE municipality of Cambridge, Ohio, founded in 1806 by Guernseyites, is commendably ambitious and justly proud: ambitious to develop and grow, and proud of its name, its record and its prospects. It aspires to be the greatest manufacturing city of its state, and claims to have the cheapest fuel, due to the proximity of about two dozen mines, producing a high-grade bituminous coal.

The last census gave Cambridge a population of 11 327. These figures were disappointing to the public-spirited citizens, who suggested a mistake on the part of the census-taker, and raised the question, "Why take the census at all, for it is so often disappointing?" Others said Cambridge would undoubtedly have made a better showing had she been provided with a bountiful supply of pure and wholesome water, and this undoubtedly is true, but the proof of it will not be forthcoming until after the census of 1920.

Cambridge has financed and is building a \$250 000 im-

NOTE. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, before August 10, 1916, for publication in a subsequent number of the JOURNAL.

* Of the W. J. Sherman Co., Consulting Engineers, Toledo, Ohio.

provement to, or perhaps we had better say, reconstruction of, the water-works system.

THE EXISTING WATER WORKS.

The water works, which are municipally owned, were installed in 1896, a supply being taken from Wills Creek without filtration, and about eight miles of pipe lines being laid. The original cost is said to have been \$63 000. There are now about $15\frac{1}{2}$ miles of cast-iron pipe in the distribution system, varying from 14 ins. to 4 ins. in diameter, more than 75 per cent. of it being 4-in. and 6-in. pipe. There is a standpipe of 200 000 gal. capacity supplying the domestic service. The two 1 500 000-gal. compound duplex pumps of the original installation are still in service, and a 2 000 000-gal. pump of similar design purchased at a later date is out of commission.

The water consumption is reported as having a range from 1 000 000 to 1 400 000 gals. per day, and an average of about 1 200 000 gals. There are 2 200 services producing gross earnings of about \$7.00 per service, the quality of the water furnished not warranting rates fair to the city. For example, \$5.00 per annum pays for all the water used by an ordinary family, including bath and closet.

The source of supply is Wills Creek, a very considerable stream draining over 300 sq. miles above the city. The slope of the stream bed is flat and the normal flow is sluggish. Occasional excessive turbidity prevents the use of meters, and none have been installed. As the stream is polluted by the twenty-six coal mines and several villages within the drainage basin, there have been numerous attempts to obtain a ground water supply, but they were unsuccessful, and so this municipally owned plant has furnished the people of Cambridge with water which was always dangerous though sometimes clear and sparkling. It is reported that the volume of flow in Wills Creek has on one or more occasions been reduced to a dangerously small amount near the end of some protracted drought. Moreover, the pumping station was small and the machinery utterly inadequate to meet the requirements, the normal station pressure

of 100 lbs. in the bottom lands being insufficient for the needs on the hills.

THE EFFORTS TO IMPROVE CONDITIONS.

It is doubtless true that Cambridge could not develop along the lines of her ambitions unless something was done to improve both the quantity and the quality of the water supply. Nor should we overlook the serious need for reinforcing and extending the distribution system into the outlying districts of the city. The problem at Cambridge was, therefore, one of reconstruction rather than of mere improvement.

While thoughtful citizens have been aware for a long time that something would have to be done to improve conditions, yet it seems to have required the added stimulus of the State Board of Health to produce results. More than fifteen years ago the State Board warned Cambridge of the dangers of impure water and the necessity of providing a source other than the raw water of Wills Creek, and the records of the board show frequent reference to Cambridge, her unsatisfactory water supply, and the need of improving it. At times the water has been so bad that even animals refused to drink it.

The public early resorted to surface wells for drinking water, thinking it safer because clearer. But there was much typhoid, and frequent analyses of well waters and hydrant water were made to determine their relative safety.

Late in 1899 the city, with the approval of the State Board of Health, abandoned Wills Creek as a source of supply in favor of one from wells pumped with air, which seemed promising, ten wells 110 to 125 ft. in depth having been drilled and provided with a large receiving well. For a time it appeared that the problem of a satisfactory supply was solved, but this and other similar efforts seem to have failed, for in 1903 the statement was made by the State Board of Health, that "the hydrant water has not improved with use, and though still preferable to the waters of Wills Creek, the analysis shows it undesirable." Shortly after this the well supply was abandoned in favor of the creek supply, which is still being used.

Commenting on the analyses made in 1905, the State Report says:

"The results are, in general, similar to those obtained from Wills Creek near the water-works inlet in 1899. These findings show a surface water containing considerable vegetative organic matter, a slight amount of sewage material, and much suspended matter. From previous analysis this is such a water as may be expected from Wills Creek at any time, although there are seasons when it is much worse. It is a water that is wholly unfit for a public supply in its present untreated condition."

It would thus appear that as long ago as 1905 the filtration of the public water supply was under consideration. All efforts to obtain an abundant supply from deep wells had failed, and the quality of the water from shallow wells was similar to that obtained direct from the creek, and the quantity was not nearly so great.

It is one thing to determine the needs of a young and growing city and quite another to finance them within the allowable limits of taxation. This financial problem is, in fact, a much greater problem in most cases than the engineering problem of planning and designing.

Cambridge has been struggling with the financial problem for a long time, and even to-day it is not the least of her troubles. None of her departments has ever been self-supporting, and the earnings of the water department have always been disappointing, ranging as they have for years a little over one dollar per capita exclusive of the public service, which pays nothing, instead of about three dollars as they should if good service were rendered. It has always been the writer's conviction that a municipality should credit its own plant with the same amounts they would have to pay a private company for fire protection, sewer flushing, street cleaning and similar service, for a public plant is entitled to the same fair treatment which a private plant demands and obtains.

In 1909 the State Board of Health recorded the fact that the city of Cambridge had "presented satisfactory evidence to show that said city is unable financially to pay for the installation of sewage purification works and remove the cause of

complaints and to install a new public water supply." So sewage purification was postponed, "provided the authorities of the city of Cambridge take the necessary measures to secure the introduction of a satisfactory public water supply without delay."

This was in January, 1909. In June, 1910, the State Board made the formal request that the city "engage the services of a competent consulting engineer to prepare plans and specifications for storage facilities, purification works and all necessary adjuncts involved in an improvement of the present water supply to an extent that will render it safe from a sanitary point of view, and will remove all objectionable physical characteristics." The project was to be completed, according to the plans officially approved, at a date not later than May 1, 1911, or in default thereof the State Board of Health would proceed according to the provisions of the so-called Bense Act, passed April 7, 1908.

Under a mistaken impression as to the probable cost of the project, the city administration on two occasions, in May and June, 1912, submitted the question of bond issues of \$75 000 and \$100 000, respectively, to the people for vote. Both failed and resulted in a mandatory order from the State Board of Health in June, 1913, to install a satisfactory water supply prior to January 1, 1915. This order was approved by the governor and the attorney-general and is now being carried out at an estimated cost of \$250 000. In August, 1915, the State Board of Health extended the time for completion to February 6, 1916.

The praiseworthy efforts of the State Board of Health looking to a betterment of the sanitary conditions of the numerous municipalities of the state had often been defeated because it had not sufficient authority properly to enforce its suggestions, requests and orders. It became increasingly apparent that the Board could not properly perform the functions for which it was created without additional legislation designed to materially increase its powers, and, through the efforts of the friends of good government, the so-called "Bense Act" was passed by the legislature on April 7, 1908. This act was entitled, "An Act to authorize the State Board of Health to require the purification

of sewage and public water supply and to protect streams against pollution," and it authorized the Board to take definite action to prevent the pollution of streams and to compel public and private corporations to furnish consumers a bountiful supply of pure and wholesome water.

Some of the provisions of this act were deemed unconstitutional, resulting in litigation which was carried through the common pleas and circuit courts to a final decision in the supreme court of the state. The decision was handed down in April, 1912, in the case of "The State Board of Health *v.* The City of Greenville," and its effect sustained the constitutionality of the so-called "Bense Act."

This Act gives the State Board of Health plenary powers, subject to the approval of the governor and attorney-general, over sewer outlets and water inlets and the construction and operation of the works necessary to purify both sewage and water. The right of appeal to a Board of Sanitary Engineers acting as referees is given the recipient of an order from the State Board of Health, and "such referee engineers may affirm, modify or reject the order of the State Board of Health submitted to them," and their decision shall be final. The bonds authorized to provide funds for carrying out the orders of the State Board of Health may not exceed five per cent. of the amount of the tax duplicate, and may be in addition to the total bonded indebtedness otherwise permitted by law, and the authority to issue need not be submitted to vote. Failure to carry out the orders of the State Board of Health subjects each offender to a fine of \$500.

Because of the delays incident to the litigation referred to, the time limit of May 1, 1911, for completing the improvements at Cambridge expired without action by the city, and an extension of time until February 6, 1916, was given by the State Board of Health. Another extension until December 31, 1916, has been applied for.

In February, 1914, The W. J. Sherman Company was engaged as engineers, and in August, 1915, the entire improvement was placed under contract, construction operations now being in progress.

THE ENGINEERING PROBLEMS.

The first problem to solve was, naturally, the quantity of water required. Then came the source from which to obtain it, followed by the question of purification or not, and if so, the method to be employed. Then came pumping station machinery, direct pressure or elevated reservoir, and finally the reinforcement and extension of the existing distribution system.

With a population of 10 569 in 1900 and 11 327 in 1910, it was deemed best to provide for a population of 30 000 and a water consumption of 3 000 000 gals. per day as the minimum requirements.

The problem of finding a source of supply proved to be the most difficult one encountered. All of Guernsey County is rough and hilly and located in the breaks of the Ohio River. The peaks are sharp and the valleys rather narrow, the former rising 300 to 400 ft. above the latter.

The search for a suitable reservoir site was diligent and thorough. One which would provide a gravity supply for the entire city was out of the question because the city itself occupies not only the entire valley of Wills Creek, but both hillsides nearly to the top. It was desirable to secure a location from which the supply would at least gravitate to the pumps in the city, and if filtration could be avoided it would be most fortunate. By far the most important consideration was the volume of supply available, this being controlled largely by the drainage area above the dam.

It is the writer's observation that in the past there have been many disappointments due to failing or insufficient water supplies. Many a reservoir has been entirely depleted, due to an insufficient drainage area; and many an underground supply has failed because of the gradual falling away of the ground water levels. Sometimes the fault lies with the engineer and sometimes with arbitrary city officials, but always the engineer is blamed; hence the importance of good, thorough engineering work and a public record for the protection of the engineer.

Among the reservoir sites examined and studied were the following:

	Drainage Area. Sq. Miles.
Chapman's Run.....	19.5
Sarchet Run.....	7.3
Peters Creek.....	9.9
Crooked Creek.....	62.0
Buffalo Creek.....	50.0
Seneca Creek.....	151.0
Leatherwood Creek.....	89.0
Salt Fork.....	163.0
Board of Trade Run.....	1.0

Since the great flood throughout the middle west in March, 1913, we have seen frequently the expression "dry reservoirs" in connection with the retention or detention of the excess of flood waters in special reservoirs, and their gradual release after all danger has passed. But there is another kind of "dry reservoir" which, instead of proving a blessing to the community possessing it, is occasionally a source of great distress. I refer to reservoirs intended for collecting and impounding water supplies for municipal use which become dry and go out of commission at times when they are most needed. There are many examples of this kind of "dry reservoirs" in America, especially in the territories subject to more or less prolonged droughts.

Statistics show that evaporation alone in the territory which includes Pittsburgh, Columbus and Cincinnati causes an average loss of about four feet per annum from reservoir surfaces. Then there are losses due to ground infiltration and dam leakage which must be anticipated and provided for in the original construction. That this has not always been done is evident from the number of reservoirs which at times fail to perform properly their functions throughout the entire dry season. Within fifty miles of Toledo there are at least two such cases, viz., at Norwalk and at Bucyrus, and it may be of interest and quite appropriate to submit some data covering these two reservoirs. Norwalk had a population, in 1910, of 7 858, and Bucyrus, 8 122. The reservoir at Norwalk impounds 500 000 000 gals. from a drainage area of 8.6 sq. miles, while the reservoir at Bucyrus impounds 155 000 000 gals. from a drainage area of 3.9 sq. miles. The water consumption is respectively 222 and 117 gals. per capita per day. As may be inferred, the former is a muni-

cipally owned and the latter a privately owned plant, and neither is metered.

In Ohio it has been demonstrated that a drainage area of one square mile will yield about 120 000 000 gals. per annum, and supply a population of 1 000 to 2 000 provided there be sufficient storage and ordinary restrictions on water consumption. It is manifest that the water shortage at Norwalk would cease with the introduction of meters, for both drainage area and storage capacity are otherwise ample. It is also manifest that at Bucyrus both drainage area and storage are insufficient.

The practical conclusions of our studies on the relative minimum requirements for drainage area and storage capacity for municipal water supplies in Ohio cities are that it is desirable to secure at least one square mile of drainage area per 1 000 population. A larger drainage area will permit of a smaller storage, and vice versa. In Ohio the minimum yield is assumed to be 25 per cent. of the minimum rainfall of 25 ins. per annum.

The minimum annual yield should be sufficient to anticipate a reasonable growth for, say, fifty years to come, but the engineer who is permitted by the authorities to plan so far ahead can be congratulated, for the cost must always be considered. The yield per square mile of catchment area was assumed for the Cambridge territory to be 25 per cent. of the precipitation for the two extremely dry years of 1894 and 1895, when 28.24 and 28.78 ins., respectively, fell in this district. This provided 123 and 125 million gallons per annum.

As already stated, the several available reservoir sites were each carefully studied with a view of determining their relative merits. By a process of elimination the number was finally reduced to three, viz., Salt Fork, Peters Creek and Board of Trade Run, and reports were made on all three projects.

It was developed in these reports that Salt Fork possessed greatest merit in available yield and permanent dependability, quality of water before treatment and safety of water after treatment, whereas the Board of Trade project had the merit of lowest initial cost, and Peters Creek that of lowest operating cost. It is proper to state here that Sarchet Run near by was available for a supplemental supply if and when required in the future.

The friendly controversy over reservoir sites between the friends of each was prolonged, with the engineers favoring Salt Fork, a very splendid project, though, costing \$150 000 more than the Board of Trade project and \$25 000 more than Peters Creek.

For convenient comparison of the three projects the following statement is given:

	RESERVOIR FEATURES.		
	Salt Fork.	Peters Creek.	Wills Creek and Board of Trade Run.
Drainage area.....	163 sq. miles	10.89 sq. miles	300 sq. miles
Reservoir capacity in gallons.....	500 000 000	700 000 000	2 12 000 000
Distance from Court House.....	6.5 miles	4.1 miles	1.5 miles
Area submerged.....	145 acres	191 acres	36 acres

The Salt Fork project, with a drainage area of 163 sq. miles, located in the back hill country with a total resident population of less than 1 000, free from mines, industrial establishments and railroads, and likely to remain so, was certainly an inviting proposition from an engineer's standpoint. But the immediate financial interests of the city prevailed, and the Board of Trade Run was finally selected.

The drainage basin of Wills Creek is larger, having an area of over 300 sq. miles. There is a resident population of about 20 000, and the basin contains numerous coal mines. The sources of pollution are rather numerous, and the water supplied the city from this source has always proved very unsatisfactory. The bottom lands are broad and largely under cultivation. The stream has a sluggish flow during normal and low stages.

There is no suitable location in the valley of Wills Creek and within a reasonable distance of Cambridge for a collecting reservoir. The flow of the stream was measured during the extremely low water of August 13, 1910, and found to be 1 320 000 gals. per day, and it is safe to say that it sometimes is as small as 1 000 000 gals. per day for brief periods.

It was early manifest that Wills Creek would afford a plentiful supply if provided with a storage reservoir of sufficient

capacity, but no suitable location was available in the immediate valley of the creek. Fortunately, however, there was a splendid location for a reservoir a short distance above the city and less than $1\frac{1}{2}$ miles from the existing pumping station.

It was known as the Board of Trade Run, well adapted by nature for a reservoir of practically any capacity desired, as the hills rise on three sides to a height of 400 ft. above the valley, and the dam at the foot of the valley, to afford a capacity of 212 000 000 gals., is but 500 ft. in length, with an extreme height of 50 ft. when the flow line is 60 ft. above the low waters of Wills Creek.

This was the reservoir site finally selected because of the low initial cost.

A reservoir capacity of 212 000 000 gals. was determined upon as being sufficient to carry the city for about four months of dry weather without replenishing from Wills Creek, from which must come practically the entire supply, as the drainage basin of the Board of Trade Run is but about one square mile.

On the banks of Wills Creek is being built an auxiliary pumping station designed to house duplicate motor-driven pumping units, each having a capacity of 2 100 gals. per minute, one for service and one for reserve. Distant control starting apparatus will be provided so that the motors can be operated from the control station $1\frac{1}{2}$ miles away. A low dam is being built at the auxiliary pumping station to raise the general level of Wills Creek about three feet at the intake.

A 24-in. gravity line from the large reservoir to the central station is to supply the filters at that point. For economic reasons this low pressure (24 lbs.), slow velocity (1.5 ft. per sec.) gravity line is being constructed of cypress instead of cast iron, the engineer's favorite material. It is expected that these wood stave pipe will render good service for thirty or thirty-five years.

Under the plan finally adopted the water must be pumped three times before it finally enters the distributing system, first from Wills Creek unto the main storage reservoir, second from the coagulation basin into the filters, and third from the clear well to the mains. All this to reduce the initial cost of the installation!

Inasmuch as double pumping was unavoidable in any event if the water was to be filtered, it was reduced to either the gravity fill of a big reservoir 6 miles away or a pump fill of a smaller reservoir $1\frac{1}{2}$ miles away at an estimated saving of \$150 000. While it is true that a richer and larger community would have selected the former site, yet in this instance it could not be accomplished, even though a saving in operating expenses of perhaps \$1 000 per annum could be effected.

Included in the original plant was a brick settling basin having a capacity of 500 000 gals. This is hereafter to be used as a double unit coagulating basin in connection with new rapid sand filters of the gravity type which are being built over one end of it.

The present water consumption is about 1 500 000 gals. per day. The filters are in four units of 750 000 gals. per day each, one of which will be left blank for the present. Space allotments are as follows: Operating floor, 1 040 sq. ft.; pipe gallery underneath has same area; chemical room, 600 sq. ft.; pump and blower room, 325 sq. ft.; chemical storage, 925 sq. ft.

Water piping within the building will in general be cast-iron flange pipe, and all chemical piping will be of lead.

Each filter has an area of 264 sq. ft. The coagulant will be either sulphate of alumina or sulphate of iron with lime, and the filtered water will be treated with hypochlorite of lime. The filtering sand is to have an effective size of not less than 0.35 and not over 0.45 of a millimeter and a uniformity coefficient of not over 1.65. There will be 30 ins. of filter sand overlaying 9 ins. of gravel graded from No. 20 mesh up to 1 in. The strainers will be of brass with headers of cast iron and a separate manifold system.

The equipment includes rate controllers, loss of head gages, rate of flow gages and recording dials, hydraulically operated valves and marble top operating tables. The wash water pump is to have a capacity of 2 000 gals. per minute, and the blower a capacity of 1 060 cu. ft. of free air per minute at four pounds pressure.

The solution tanks will be of concrete with an orifice box for each tank. The guaranty requirements provide that filtered

water shall contain no decomposed coagulant, shall be free from odor due to the chemicals used, and shall be bright, clear and free from color, turbidity or suspended matter visible to the eye.

The filtered water must show an average reduction of bacteria of not less than 98 per cent. when the number in raw water exceeds 3 000 per cubic centimeter and not more than 100 bacteria per cubic centimeter when the number in the raw water is less than 3 000 per cubic centimeter.

The clear well adjoining the filter plant is to have a present capacity of 210 000 gals. and an ultimate capacity of double that amount.

While the new pumping station will occupy the same site as the old one, the entire station will be reconstructed, providing a new brick stack (54 ins. by 110 ft.), brick building, gravity coal chute, two 3 000 000 gal. cross compound, crank and fly wheel pumping engines and one 150 h.-p. boiler.

The pumping engine while delivering 2 100 gals. per minute against a pressure of 150 lbs. is required to develop a duty of not less than 135 000 000 foot-pounds and a half-speed duty of not less than 100 000 000 foot-pounds per 1 000 lbs. of dry steam.

American Water Works Association Class C pipe is being used throughout, in the construction of the 10 miles of new mains, to reinforce and extend the distribution system. All pipe laid is tested to 175 lbs., and all leaks stopped before the trenches are backfilled.

The speaker is deeply impressed with the great importance of this requirement and the fact that engineers seldom enforce it. The result is a continuous leakage and waste which cannot be accounted for, amounting in some instances to as high as 25 per cent. of the total pumpage.

The plant, while possessing a small standpipe, has in recent years been operated as a direct pressure system, and will so continue, although there is a considerable demand for an elevated reservoir on one of the nearby hills known as "Gorley Hill," and it is possible that such a reservoir may be built at a later date.

BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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DETERMINING THE WEIGHT OF STONE IN VESSELS.

BY A. S. ACKERMAN,* MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

THIS paper considers several methods of determining the weight of cargoes of stone, with special reference to a comparison of the two methods last given.

The first method is the direct one of passing the cargo over scales, usually in flat cars from the quarry, when the net weights of the loads are taken. The carloads are then placed on board the vessel as soon as weighed until a complete cargo is obtained, and the sum of all of the carloads gives, of course, the total weight of the stone cargo. Since the stopping of the flat car at the scales for weighing materially increases the time of loading the vessel, the elimination of this step is desirable. Again, apparatus for weighing large quantities of stone in a short time is not installed at most quarries, nor is it necessary, since the production and sale of rubble stone is generally secondary to the principal output of the quarry. Furthermore, at many quarries there are either no scales or only inconvenient or unreliable ones. This method is accurate, and might be used if the weight of cargo were desired only once. If, however, the determination of cargo weights of successive trips is needed, the fact that this method requires a repetition of the whole operation is the strongest argument against its use.

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The second method, that of computing the volume and reducing to weight, is very wide of the mark, but has sometimes been used for small quantities. Even the most experienced inspector probably cannot estimate to within 10 per cent. the volume of a cargo as it passes before him. Moreover, this method necessitates the constant attention of one man, and the result is further affected by any error in the assumption of the weight per unit volume of stone, or if the unit volume is actually weighed, by the variation in weight of a unit volume. Likewise, if a rule is put on each block of stone, which adds to the labor, the result would be nearly as inaccurate, and in reducing volume to weight the result would again be further affected by the variation in weight per unit volume of the stone from different quarries, and even from the same quarry. Also, even while honestly intending to be fair, the man who estimated the cargo of a vessel in this way would be biased in his decisions.

The third method is that of "weighing-in." In determining the weight of a cargo of stone in this way, a method is used which is related to that of obtaining the weight by "displacement" (which follows), since the latter is a factor of both. In other words, the two methods are analogous, since they differ only in the procedure of obtaining values for the curves or tables used. In "weighing-in," the stone is passed over the scales and placed on board the vessel, readings of displacement being taken fore and aft for successive loadings. At the beginning and at the end the load intervals for recording drafts are taken smaller than near the middle in order to establish the curve better at points of more sudden change. Intervals of from 20 to 25 tons, evenly distributed in the hold of the vessel, are usually taken at the start, which may be increased to 50, 75 and 100 tons as the loading proceeds, the intervals being again reduced near the completion of the loading, although the curve at the upper end does not change as fast as at the lower end. The displacement is usually read on two gages, which are vertical glasses set against broad boards located with reference to some immovable and unchangeable points on posts over the keel of the vessel near the bow and the stern. The glasses, or boards, are calibrated to even tons from the results of notes taken at the "weighing-in,"

by making a plot of recorded drafts to form a displacement curve from which interpolated values are placed on a gage board drawing for record, after which they are scribed on the gage board itself.

The operation of "weighing-in" a vessel takes some time, in a certain case as much as two weeks, as the quarry owners usually are unwilling to make the operation of primary importance to them, and it can be seen that it is a comparatively costly method, including, as it does, the salary and expenses of an inspector and the cost of weighing stone and establishing gages in the vessel. Nevertheless, where the amount of work to be done warrants it, the method is preferable, as it is somewhat easier to read the gages. It is sometimes desirable to make use of a mid-length gage to take care of the "hog" in vessels of larger size.

In the fourth or "displacement" method, a displacement volume of the vessel is obtained well outside the maximum and minimum limits, which reduced to weight gives a mass curve from which loads can be directly taken. The procedure is as follows:

The draft marks of a vessel are taken at the stem and stern loaded and again when lightened and pumped out. In the latter condition the vessel is measured, an operation which occupies about an hour after men have become accustomed to taking measurements. The length is taken horizontally on deck, forward of the after part of the stern post, which is called station zero, to a point just forward of the loaded mark on the cutwater, the length being divided into stations of ten feet, and at the bow, sometimes, of five feet. At these stations the semi-widths are obtained to the outer edge of the rail, and then at each succeeding station offsets from a plumb line, hung from the rail by means of an outriggered stick so that the line just touches the side of the hull at the widest part of the section, are taken to the side of the hull at each even foot above light water line, the plumb line being tagged every foot. These measurements are taken as carefully as possible horizontally and normal to the axis of the vessel; and the distance subtracted from the semi-width at the rail plus the distance to the plumb line from the outer edge of the rail gives the semi-width of the vessel at each even foot plane above light

water line for each station. After measurements are taken at all stations, the slant of the cutwater and sternpost is obtained in the same manner. Each station section taken as above is plotted on cross-section paper and a curve faired through all the points, which is taken as the mold of the hull at that station for the distance displaced. From these sections distances are taken and a horizontal section of the hull plotted for each foot above light water line. These areas are then planimetered and the volume for each foot computed and plotted as a curve. In determining the cargo carried by a vessel, the mean of the bow and stern displacements is read off the curve, giving the tons directly. In computing the weight, that of sea water is assumed as 64.2 lbs. per cu. ft., and tons are obtained in units of 2 000 lbs.

The two latter methods of weighing stone were used in connection with the building of the Cape Cod Canal breakwater. The method by "weighing-in" was used after a considerable amount of stone had been placed, as during the first season none of the vessels had been weighed in. At this period stone was supplied in sailing vessels, and no way of determining the weight of the cargoes had been provided. The method of determining it by "displacement" was, therefore, suggested by Mr. Eugene Klapp, deputy chief engineer, and developed under the writer, who was then division engineer.

After the first season's work the vessels were weighed in and several cargoes were compared by the two methods. The agreement was very close, the difference being in one case about two tons and in others not more than ten tons. This shows that the two methods last mentioned compare favorably for certain vessels and that the two may be considered of equal value, for the readings of the draft marks in either case are subject to the same errors. The cost of measuring a vessel for the "displacement" method is slight, as three men can easily perform the task in about an hour, after attaining skill, and the office work is about the same as for "weighing-in." The accuracy of the "displacement" method of course depends, among other things, upon the value of the weight of a unit volume of water, but this can be determined by direct measurement.

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PAPERS AND DISCUSSIONS

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SLIDE RULES FOR REINFORCED CONCRETE DESIGN.

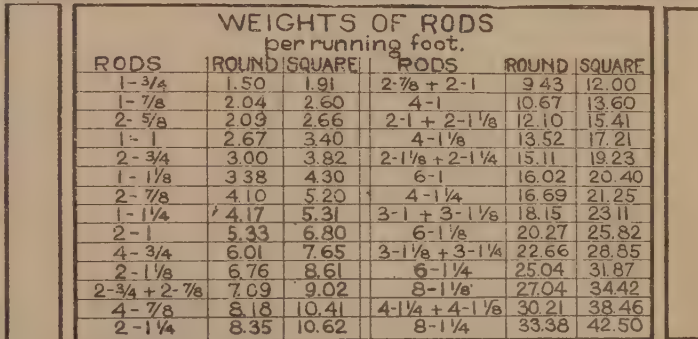
By E. F. ROCKWOOD,* MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

THE accompanying illustrations show the fronts and backs of two slide rules for use in the design of reinforced concrete beams and slabs, respectively. These rules were originally designed by the writer in 1908, and constant use of them since that time has developed them into their present forms. Full directions for their use are printed on them.

These slide rules have never been put on the market, although the Architectural Department of the Massachusetts Institute of Technology has had a limited number made up for the use of students. In order to assemble one it should be mounted on stiff cardboard, the slides cut out and the remainder of the front pasted on the back in such a way that the slides will occupy the positions shown in the cut. Transparent celluloid should then be fastened to both front and back by means of small rivets or eyelets in order to protect the paper and to form a channel for the slides.

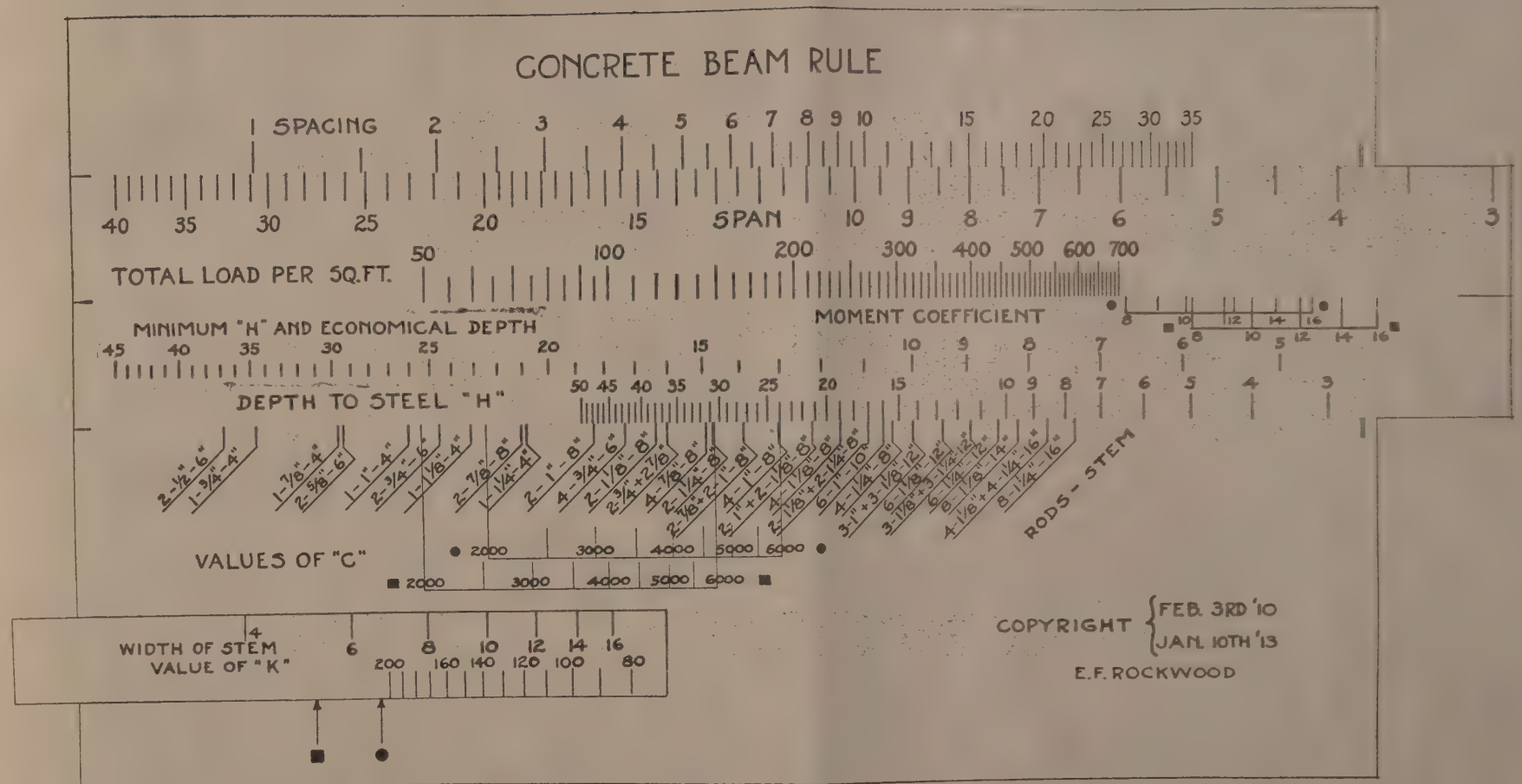
Permission is hereby given to cut out and mount the set printed in this issue of the JOURNAL.

* Chief Engineer, New England Concrete Construction Co., Boston.

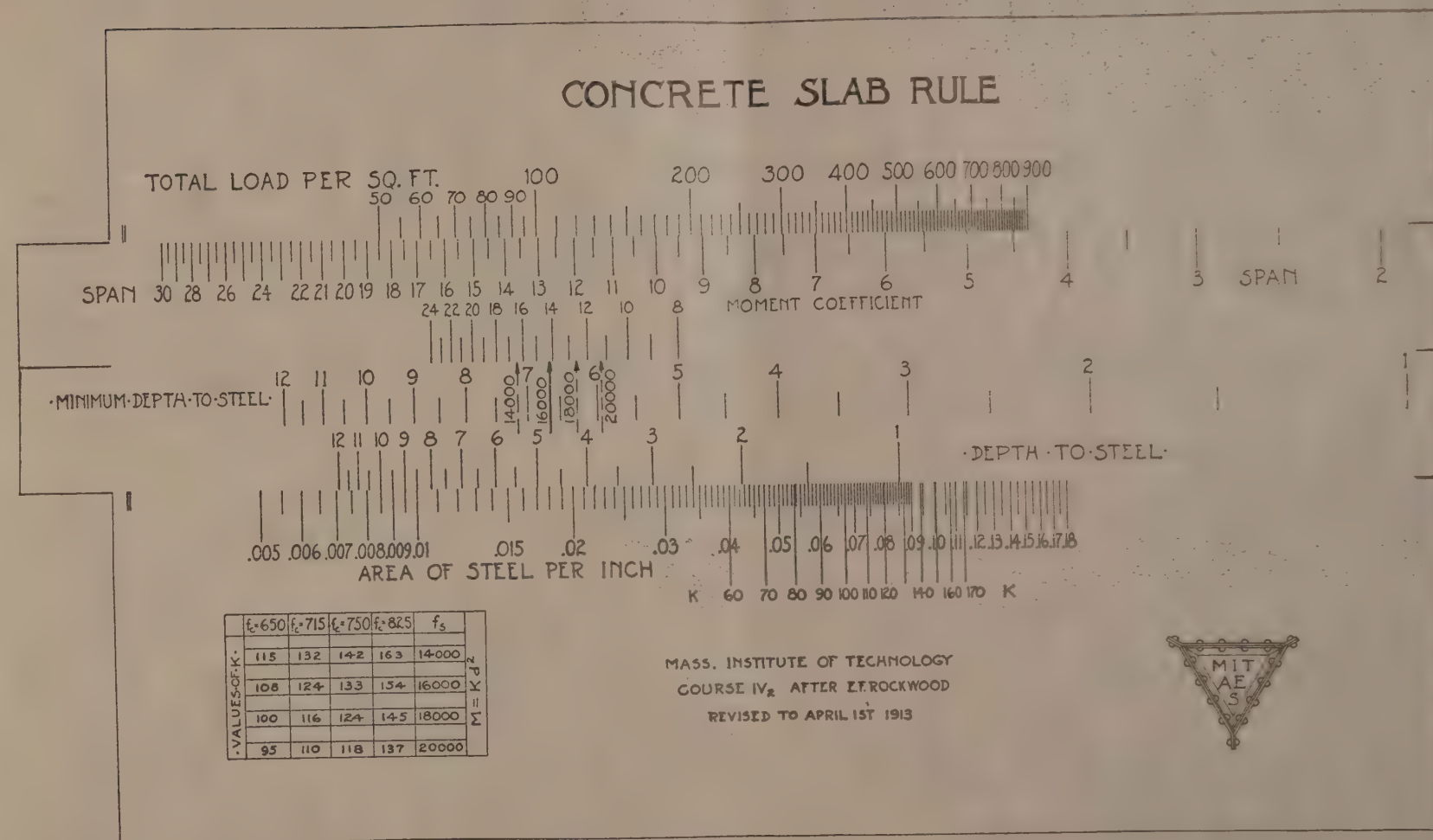
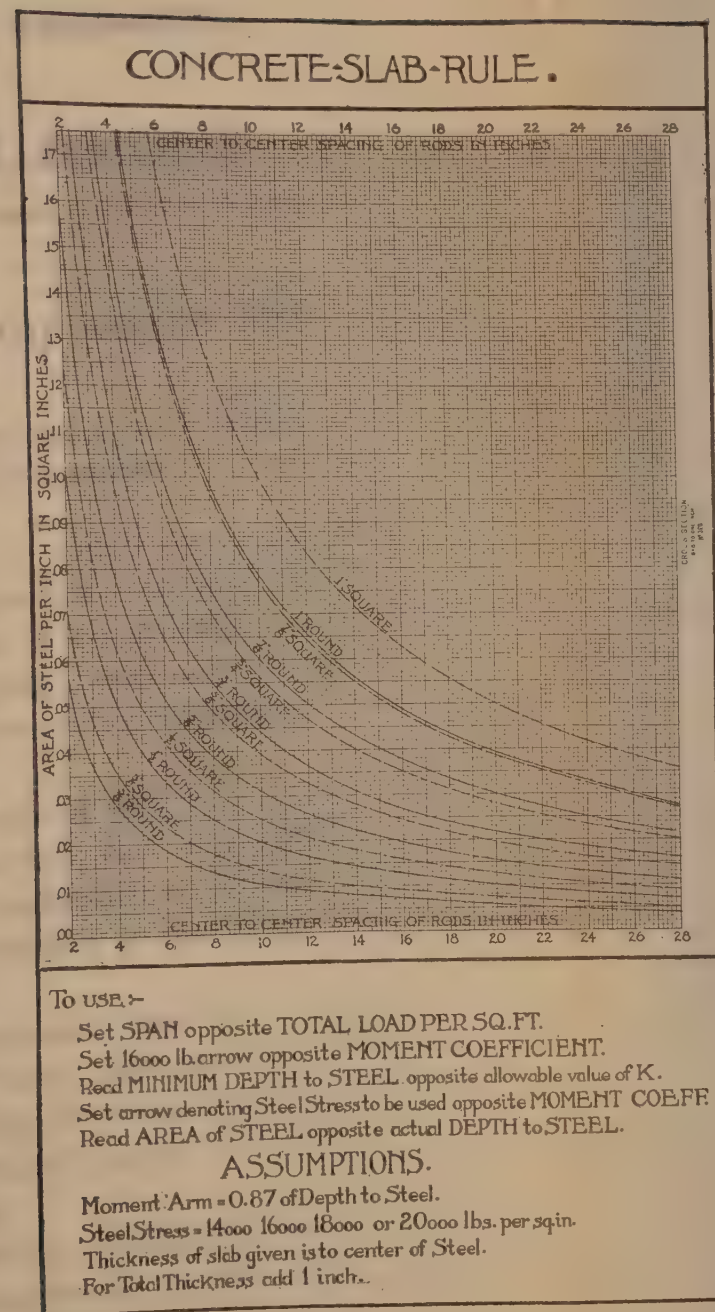


TO USE —
SET SPAN OPP. SPACING.
SET MOMENT COEFF. OPP. LOAD.
USE SET THAT CORRESPONDS TO
KIND OF RODS TO BE USED.
OPP. "C". AS DETERMINED BY
PLOT ABOVE, READ ECONOMICAL
DEPTH TO STEEL.
OPP. DEPTH TO STEEL USED, READ
NUMBER AND SIZE OF RODS, AND
MINIMUM WIDTH OF STEM.
FOR □ SECTIONS— $M = K b d^2$
SET "K" OPP. ARROW, OPP. WIDTH
OF STEM, READ MINIMUM DEPTH
TO STEEL.

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E.F. ROCKWOOD.



SLAB RULE.



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DISCUSSION OF "SAND AND OIL ROADS AND
SURFACES."

BY MESSRS. A. B. FLETCHER, C. M. UPHAM, L. W. PAGE, W. P. HAMMERSLEY,
JOHN M. KEYES AND W. R. FARRINGTON.

MR. A. B. FLETCHER * (*by letter*). — Oiled dirt roads were first built in California in the early nineties. It was, however, between 1900 and 1904 that this type of construction received the greatest attention, and in 1904 some 2 000 miles of county roads and about 500 miles of city streets so built were under traffic.

The percentage of failures of roads of this type is so very high, and the cases where the construction can be regarded as a success are so rare, that, except as a makeshift or in cases where road funds are very low, this construction is but little used in California to-day.

The California Highway Commission has in a few cases made use of oiled dirt roads where heavy fills on new construction required protection from cutting by rain until such time as the fills became sufficiently settled to be satisfactory for concrete or other type of pavement.

Unfortunately, the records kept by county and city officials in this state give but little information as to the character of the oil used. In most cases it was a natural crude oil, contain-

* Highway Engineer, California Highway Comm.

ing from 30 to 60 per cent. asphalt and having a gravity of from 12 degrees to 14 degrees Baumé. The specific viscosities of such oils vary from 1 to 10 (Engler test 100 c.c. at 77 degrees fahr.).

Mr. Farrington's paper deals chiefly with oiled sand roads, and in this particular the work differs from the great bulk of the crude oil roads of California, which generally were built of dirt combined with oil.

The California asphaltic oils, both crude and the heavier manufactured road oils, all show a marked hardening on exposure to weather. The oiled dirt or sand under traffic is generally forced into an uneven surface, partly due to the lack of support of the underlying base in the weak spots of the road and partly due to the fact that a very slight excess of oil in the surface makes a composition which tends to flow to lower elevations. The shoulders of oiled roads in time have a thicker and thicker mat of rather spongy surfacing, too hard to iron out by rolling and too irregular to make pleasant riding.

This construction and the results obtained in California are here discussed somewhat in detail in order that by comparison with the roads described by Mr. Farrington some explanation may be found for their success in Massachusetts.

The "layer roads" described by Mr. Farrington first of all have a hard, properly shaped sub-grade. Clay is added to sandy parts of the road to make the sub-grade a real support for the surface. The oil is applied hot and in two or three applications. The mineral aggregate after each application is spread over the surface of the oil and, due to the higher specific gravity of the sand and by rolling the sand into the oil, it is forced to take up a much higher percentage of aggregate than is found possible under the method used in California.

The oiled dirt roads of California usually after a year or more of weathering will show from 8 to 10 per cent. of bitumen. Mr. Farrington states that $1\frac{1}{3}$ gals. used in the layer treatment gives a thickness of about $3\frac{1}{2}$ ins. This would be only about 4.2 per cent. of bitumen. The oiled sand roads of California show from 7 to 10 per cent. of bitumen. With as low as 4 or 5 per cent. of bitumen the oiled surface should have no tendency to flow or move due to gravity, and where forced out of shape

by traffic the oiled surface should be more easily repaired by breaking it up by a scraper and rolling it again to a true surface. This is not the case where the oiled surface contains 8 or 10 per cent. of bitumen. A tough, leathery mass is then formed, which is almost impossible to break up with a scraper.

The actual hardening of the California asphaltic oil, while a benefit in some types of surfacing, is an added handicap when the oiled dirt road once loses its even surface.

Mr. Farrington describes the construction of "mixed sand and oil surfaces." In this construction various grades of oils and asphalts were used. The product somewhat resembles a standard sheet asphalt in which the sand is rather coarser than would be desirable for such a pavement. The coarser sand and the lack of dust would account in part for the construction with as low as 4.5 per cent. of asphalt. This must be a very "dry" bituminous surface, and under any heavy traffic there must be a tendency to crush and break up.

Mr. Farrington says that the best results were obtained by using about 18 gals. of asphalt per cubic yard of compacted sand. This would give between 4.5 and 5 per cent. of asphalt. This asphalt content seems very low.

In determining the proper amount of asphalt to be added to a Topeka surfacing, it is usual to allow asphalt to the amount of about 4 per cent. of the weight of the coarse rock to cover the rock surfaces. That is, if 25 per cent. of rock (passing No. 2 sieve and retained on No. 10 sieve) were used, then $4\% \times .25 = 1.0\%$ of asphalt must be added for the rock. The fine sand and dust will make up about 66 per cent. of the surfacing and will require asphalt to the extent of about 12 per cent. of the weight of the sand. That is, $12\% \times .66 = 7.92\%$. The final mixture would be —

Sand,	66%
Rock,	25%
Asphalt $1\% + 7.9\%$, .	<u>9%</u>
	100%

It should be emphasized that 4 per cent. of asphalt is regarded as only enough to coat the coarse aggregate, and where

the sand is as fine as is required for a standard sheet asphalt pavement, as high as 12 or 13 per cent. is regarded as necessary.

Certainly the present-day practice in Topeka or sheet asphalt construction does not indicate that a mixture containing only 4.5 to 5 per cent. of asphalt would be "live" or capable of resisting any but very light traffic where the sand is as fine as even the coarsest sand used in the Massachusetts work.

Reverting again to the California oiled dirt roads, it should be explained that sand such as is so common on Cape Cod in Massachusetts is rarely found in California. To transport suitable sand by rail for use with oil would cost more than the result would warrant.

The California "oiled dirt" roads were so named accurately. All materials from adobe to fine sand were treated with oil during the craze.

As already stated, this type of road surface has been abandoned to all intents and purposes, and recently, Tulare County, the home of one of the most skillful of the "oiled road" exponents, has declared that it has "outgrown oiled roads" and needs a better type of pavement.

MR. CHARLES M. UPHAM * (*by letter*).—After reading Mr. Farrington's very complete paper on "Sand and Oil Roads and Surfaces" it appears there is little that can be said in the way of discussion. A few remarks along this line describing experiments performed in Delaware which differed slightly from the Cape Cod construction may be of interest.

As a rule, our sand is much finer, many times all of it passing a No. 10 sieve. It also contains a very large amount of 200-mesh material; sometimes as high as 15 and 20 per cent. Several "layer method" experiments were attempted but none proved successful, the reason being that when an asphaltic oil that would mix with the extremely fine sand was used, it was such a light oil that it had no binding power. Five months after the experiments were tried it would be difficult to find any traces of them. This method was abandoned as a failure.

Several pieces of mixed sand and oil surfaces were laid and, with but one exception, with perfect results. The materials

* Chief Engineer, Coleman Du Pont Road, Georgetown, Del.

were mixed by hand, the sand being heated on pipe heaters. The sand was very fine, about 55 per cent. passing the 50 sieve and 22 per cent. passing the 100 sieve.

Heavier binders were used in the Du Pont Road experiments, the lightest being of 70 degrees penetration (Dow). The low penetration binder and the fine sand made it difficult to mix, but no surface was laid until every particle of sand was coated with binder.

Tests show there was used 5.9 per cent. of binder by weight. The binder used was a petroleum residuum, slightly blown. The consistency of the binder made a pavement that did not soften in the hot weather any more than does a city asphalt pavement. Horse traffic did not "pick up" or "pit" the surface, as is the case when a lighter binder is used, nor has it shown any signs of being brittle in cold weather. One piece has been down nearly four years, and apparently is good for many years more without maintenance. There is medium heavy traffic on this piece of road.

The success of sand asphalt surfaces in this locality can be attributed to the natural grading of the sand and the consistency of the binder that was used, together with the perfect construction, which means having the sand hot and dry, the binder of the proper temperature and the mixing complete.

In no instance has there been used in the Delaware sand oil or sand asphalt experiments any binder with a consistency about 70 at 25 degrees cent. (Dow). The theory was advanced that the low penetration binder would become brittle in the colder weather. Zero weather has not accomplished this, and the experiments have passed through four winters.

In one of the experiments 65 degrees penetration binder was used with a coarse sand. During the first spring a hole developed in the surface. This is attributed to the absence of fine material in the very coarse sand that was used and not to the low penetration binder, as some of this binder was used on an experiment in the same locality where fine sand was used, and it is now in excellent shape and has the appearance of an asphalt pavement.

The thickness of the surface varies from 3 ins. on good

foundation to $4\frac{1}{2}$ ins. on the poorer foundations. A seal coat was used in each instance. Cement was tried as a filler, but this proved very costly and it was found by laboratory experiment that any fine material would serve practically the same purpose. Laboratory experiments showed the finer sands as a class to give the most strength.

In summation, the Du Pont Road experiments differed from the Cape Cod construction to the extent of using a finer sand and a heavier binder. By using the heavier binder, horse-drawn traffic has had no more effect on the surface than it would have on an asphalt pavement, and the surface is not dependent on the auto traffic to keep it smooth, as is the condition when lighter binders are used.

The best results in the Du Pont Road experiments were obtained using 65 degrees penetration petroleum residuum.

Laboratory results showed the strength of the sand asphalt pavement to depend greatly on the presence of fine material in the aggregate, and within certain limits they showed that as the fine material increased the strength was increased proportionally. The granulometric analysis of a sand that gave excellent results is given below.

AVERAGE GRANULOMETRIC ANALYSIS.

Amount passing 200 sieve.....	6
" " 100 ".....	15
" " 80 ".....	27
" " 50 ".....	55
" " 40 ".....	70
" " 30 ".....	84
" " 20 ".....	91
" " 10 ".....	98

MR. LOGAN WALLER PAGE * (*by letter*). — In Mr. Farrington's most interesting paper on sand-oil construction, a suggestion is made relative to improving this type of road for heavier loads and horse-drawn traffic, by mixing the sand with filler and a bituminous material of lower penetration. In this connection it may be of interest to cite a few facts regarding a

* Director, Office of Public Roads and Rural Engineering, U. S. Dept. of Agriculture.

recent experiment carried out by the Office of Public Roads and Rural Engineering at Ocala, Fla. The sand throughout the section in which this experimental road is located is fine but very well graded, being, in fact, about what is required in sheet asphalt work, as shown by the following analysis:

SAND USED AT OCALA, FLA.

Passing	10-mesh sieve,	retained	on	20-mesh sieve.....	1.2%
"	20	"	"	30 " "	4.0%
"	30	"	"	40 " "	7.4%
"	40	"	"	50 " "	11.7%
"	50	"	"	80 " "	31.8%
"	80	"	"	100 " "	14.8%
"	100	"	"	200 " "	20.9%
			Passing	200 " "	8.2%
					100.0%

After light rough grading, the subgrade was shaped with hand tools and hand rolled at a cost of 2c. per sq. yd. A hot sand and asphalt mix, carrying from 9 to 10 per cent. of an oil asphalt, having a penetration of 50 at 25 degrees cent. under a load of 100 grams applied for five seconds, was prepared in a Blystone concrete mixer. Part of the section was laid in two layers, the lower one having a thickness of 2 ins. compacted, and the upper one of $1\frac{1}{2}$ ins. compacted. The remainder of the section was constructed in a single layer having a compacted thickness of $3\frac{1}{2}$ ins.

No particular difficulty was experienced in either method of construction, although the single-layer method seemed preferable on account of the fact that it was easier to secure a true surface, and all danger of parting between the two layers was eliminated. On the other hand, it is doubtful whether maximum compression was secured throughout the entire thickness of the course. In this work it was found possible to handle the hot material from dumping boards along the sides of the road. Where this cannot be done it will of course require special attention to maintain a uniform subgrade and to reshape it after teams have passed over it; also, where practicable, to harden it by the addition of clay or loam, as recommended by Mr.

Farrington. On large contracts it is possible that arrangements could be made for handling the material by means of a dinky engine outfit operating along the shoulders. The road above mentioned was constructed in June, 1915, and has to date given satisfactory service under both motor and horse-drawn traffic, of which the latter includes considerable logging.

The necessity for a seal coat on sand-oil construction is not clearly evident, since it is never employed in sheet asphalt work. Should Mr. Farrington carry out his suggestions of using a harder bituminous material and increase the amount of this material so that it will be from 9 to 12 per cent. by weight of the finished mixture, it is believed that a seal coat will be found to be unnecessary, as in the experiment at Ocala.

Referring to Mr. Farrington's discussion of bituminous gravel construction, an analysis is given below which is fairly representative of about 7 000 lin. ft. of this type of construction which was laid by the Office of Public Roads and Rural Engineering during the summer of 1915.

BITUMINOUS AGGREGATE, USED ON MT. VERNON AVENUE EXPERIMENTAL ROAD, VIRGINIA.

Passing 1-inch screen, retained on $\frac{3}{4}$ -inch screen.....	6.7%
" $\frac{3}{4}$ " " " " $\frac{1}{2}$ " "	11.4%
" $\frac{1}{2}$ " " " " $\frac{1}{4}$ " "	19.9%
" $\frac{1}{4}$ " " " " 10-mesh sieve	12.2%
" 10-mesh sieve, " " 20 " "	6.5%
" 20 " " " " 30 " "	10.5%
" 30 " " " " 40 " "	11.4%
" 40 " " " " 50 " "	8.9%
" 50 " " " " 80 " "	6.1%
" 80 " " " " 100 " "	0.8%
" 100 " " " " 200 " "	2.8%
Passing 200 " "	2.8%
	100.0%

The gravel in this case was a natural bank gravel which seemed to be peculiarly adapted to work of this character. The mixture was prepared in a well-designed portable paving plant and laid to a finished depth of 2 ins. over a well-compacted foundation of the same gravel about 6 ins. in thickness. While this

mixture rolled to a fairly dense surface, it was considered advisable to apply a seal coat, of approximately $\frac{1}{2}$ gal. per sq. yd., of bituminous material with a covering of pea gravel. In fact, it is believed that unless the gravel is so graded as to give an exceptionally dense mixture, a seal coat will always prove desirable in construction of this character.

MR. W. P. HAMMERSLEY.* — Before taking up the discussion of Mr. Farrington's paper, it may interest you to know something of the difficulties we experienced in building the first sand-oil roads in Massachusetts. In the spring of 1906 I was sent down to Eastham on Cape Cod by Mr. Farrington, to finish the sand-oil work which had been started the preceding fall. On my arrival I found about half a mile of black, sticky material through which teams had tried to pass (when they couldn't go elsewhere) and which had been badly rutted, while here and there would be a mound or depression where the wheels of passing vehicles had accumulated all they could carry and then dropped it in a pile, the depressions representing the places where it had been picked up by sticking to the wheels, and the mounds where they had dropped their loads. There were also numerous chickens, birds, rats and a muskrat which had been trapped in trying to cross the road.

The instructions I received were rather vague as I remember them, but I understood that the mixture was to be cut up with harrows, raked into shape and rolled. Now that seemed easy, but I assure you that before the job was finished I was about ready to throw up my hands and quit. In the first place, it was mighty hard to get a harrow through the mixture; and in the second place the oil would stick to the disks and finally clog them, or it would stick to the horses' feet until the poor animals were mired. However, after due time and perseverance, we succeeded in mixing enough sand with the oil so that we could, by the aid of plenty of horses and a road scraper, get the road into shape to allow rolling with a horse roller. Then came the task of applying oil on the section not previously covered.

As Mr. Farrington states, the oil was received in tank cars

* Superintendent of Streets, New Bedford, Mass.

supplied with steam coils, to which we attached a boiler, and heated to the necessary temperature so that it could be handled (usually about 200 degrees fahr.). It was then pumped into the most primitive oil distributor you can imagine, — an old upright wooden watering cart supplied with a 4-in. distributing pipe about 7 ft. long, in which two rows of holes had been drilled. Sleeves with corresponding holes, and supplied with handles for adjusting the flow, enveloped this pipe. The shut-off consisted of a weighted wooden clapper over the inlet to this pipe on the inside of the tank, and was operated by a man riding on the top of the cart pulling on a rod attached to the clapper. This did not always work, and usually refused to close when the team became mired, resulting in a surplus of oil being applied at that particular place; also the hot oil caused the wooden tank to shrink so that about as much oil leaked out as was let out through the distributor pipe, necessitating calking the tank very often. Four, six and even eight horses have been required to pull that unmentionable oil cart through some of the soft places. We finally succeeded in putting the oil on the road and working it over with harrows and rakes until we got it into shape so that teams could travel over it without getting stuck.

I might add that people living in Eastham were obliged to change their shoes before entering their homes, and the men working on the road, including myself, were obliged to change our clothes in the barn before we were permitted to go into the house.

I recall a visit of some state officials to the job, one day, when one of the party remarked, "Hammersley, you have my sympathy in trying to make a road out of that stuff"; and if I am not mistaken, our own commissioners had practically made up their minds to cover it up with broken stone or other material. However, it is still there and is really a very fair road. Strange as it may seem, a year or so later, after we had forgotten our previous troubles, it was decided to make another attempt on the road between Orleans and Chatham, and here we had many of the same troubles again until we began to harden the sub-grade and apply the oil and sand in alternate layers.

Without wasting any more time in reminiscences, I will

take up the discussion of the very fine paper which Mr. Farrington has presented and from which he hasn't omitted anything essential.

SAND-OIL LAYER ROADS.

As stated by the author, the first method pursued was simply to shape up the road as it was found, apply the oil and work sand into it by harrowing, raking and rolling. Later the layer method was used, where the road bed was slightly hardened and the oil and sand applied in alternate layers. He stated that either two applications of $\frac{3}{4}$ gal. each or three applications of $\frac{2}{3}$ gal. each were made. From my experience I am convinced that the latter method is preferable, as it is almost impossible to get thickness enough with two applications to hold up, until the next application is made, even the light traffic of the lower Cape roads. Sufficient time should elapse between the applications to allow the oil to take up as much sand as possible and to allow the lighter oils to evaporate; and as fast as any surplus oil appears on the surface it should be covered, before it is picked up by the wheels of passing vehicles. As to taking care of the weak places which develop, I believe if more attention is paid to the proper construction of the foundation for the oil and sand, the number of these places will be greatly reduced.

My experience has been that ruts and holes usually appear where the roadbed was soft or where cuts had been made in the preliminary grading. These places should be well hardened and thoroughly compacted by rolling before applying the oil. For material for hardening the foundation, I found that sandy loam was generally better than clay, as the tendency with the latter is to apply too much or not thoroughly mix it with the right proportion of sand, so that it would heave and soften up from frost action the following spring, causing the road to rut badly and finally cut through under traffic.

This has been the case, I think, with nearly every road where any amount of clay was used. A layer of sand about $\frac{1}{2}$ in. in thickness should be spread on this foundation before applying the oil. Mr. Farrington states that the best results are obtained by the use of an oil having a viscosity of 500 to 600. It is possible

that a slightly heavier oil would give additional stability, but it would have to be applied under favorable conditions in order to incorporate the proper amount of sand. That the shape and grading of the sand has much to do with the success of this or any other type of asphalt surface is without question, as roads where beach sand was used generally rutted badly, until more or less sharp sand was added. This was probably due to the lack of grading, to the round particles making up the beach sand, or to both, but I am certain that the surface was greatly improved by the addition of sharp sand. I have in mind a section of road that rutted badly until some very fine sand was added, after which it became quite smooth, indicating that attention should be paid to the quality and grading of the sand used.

As to the best type of distributor to use, I should say that a pressure machine hauled by a steam roller would give most satisfactory results, or a small truck would be excellent if the sub-grade has been thoroughly hardened and rolled.

MIXED SAND AND OIL WORK.

While apparently fair results have been obtained by the use of the hot mixer for combining the sand and oil, I am of the opinion that enough better results would be obtained to amply justify the extra cost of a small portable asphalt plant. This type of plant has been greatly improved during the past year, is economical to operate and easy to control. They are supplied with wide wheels and can be hauled over ordinary roads by auto truck or steam roller. There are many advantages to be gained by the use of a plant designed especially for mixing asphalt pavements, over the hot mixer, which is nothing more than an ordinary concrete mixer supplied with a fire blast.

It is generally conceded by those experienced in making asphalt pavements that a satisfactory mixture cannot be secured with a plant in which the flame comes in direct contact with both the asphalt and the aggregates, the principal objection being that the flame carries with it an excess of oil, which tends to grease the surfaces of the particles of sand and stone so that

the asphalt fails to adhere to them, destroying the adhesive qualities of the mixture. In a properly constructed asphalt plant, the flame is applied on the outside of the drum, is carried the length of the drum, usually 10 or 12 ft., and then drawn back through the center of the drum to the stack; in this way any surplus oil is consumed before coming in contact with the aggregates. Another objection, and probably one of greater importance, is that the asphalt, after being heated in kettles and delivered into the mixing drum into which the flame is blown, is in danger of being burned, or heated to such a temperature that the cohesive qualities are again injured and the lighter oils are at once consumed, making a mixture which can only be handled under favorable temperature conditions. Moreover, the sand cannot be heated uniformly where pipes or arch heaters are used for this purpose.

The detrimental effects of this mixing may not show up at once in the finished pavement or even in a year after the road has been opened to traffic, especially if a seal coat, which serves as a protection against the destructive effects of traffic, has been applied. Personally, I think this seal coat is the only thing that prevents surfaces mixed in a hot mixer from going to pieces in a year or two. This can be overcome by the use of a plant where the asphalt and aggregates are heated separately and are mixed in the pug-mill type of mixer and where each operation in obtaining an even temperature and uniform mixture can be easily controlled. This, I can assure you, is anything but easy with a hot mixer, and results in a finished pavement which is neither homogeneous nor of uniform density. A saving of about 10c. per cu. yd. can be made in the cost of heating the sand by using an asphalt plant as described instead of arch or pipe heaters, comparative costs being approximately 25c. and 35c. per cu. yd.

In regard to the quantity of oil used, Mr. Farrington states that best results have been obtained with about 16 gals. per cu. yd. of loose sand, an amount which gives approximately 4.8 per cent. in the finished pavement. From records of successful asphaltic concrete pavements which have been in use for a number of years, it would seem that the mixture should

contain from 8 to 10 per cent., depending of course on the grading of the aggregates, the finer material requiring more asphalt than coarse aggregates.

More or less trouble has been experienced by "balling" of the asphalt, which was attributed to the sand not being thoroughly dried or to lack of oil, but probably the real cause was lack of 80- and 100-mesh sand in the mixture.

In regard to rolling, I do not favor the use of a horse roller as it is almost impossible to get the indentations caused by the tamping effect of the horses' feet out of the surface. I believe that the best results can be obtained by the use of a small tandem roller, weighing about three tons, followed up with a 10-ton roller. The rolling should be begun while the mixture is still hot, else the maximum density will not be secured. This would also allow the mixture to be scraped to an even surface before it has had a chance to become hard, and would result in getting a smoother road.

The trouble caused by shoving and moving of the mixture during the preliminary rolling can be overcome to a certain extent by preparing a hard, smooth and unyielding subgrade. Cross rolling will also aid in removing some of the irregularities in the surface.

In regard to the consistency of the asphalt used for the sand and oil mixture, I would choose an asphalt somewhat heavier than that mentioned by Mr. Farrington as giving the best results, and I think this is borne out by the statement he makes when he says that "if the grains of sand are rounded, and especially if the sizes vary but little, etc., a very heavy asphalt gives the best results." It seems to me the same thing holds true with any sand, and I think that a more stable mixture will result from the use of an asphalt of from 60 to 70 penetration. As for the aggregates, it seems to me that a mixture of approximately 25 per cent. of sand and gravel which will pass a $\frac{3}{4}$ -in. and be retained on the $\frac{1}{4}$ -in. screen with 65 per cent. of the sand graded as for sheet asphalt and 8 to 10 per cent. of asphalt would be satisfactory for such roads where this type of surfacing would be used. While it is usually difficult to find sand containing enough of the finer particles, a small amount

of stone dust or what is commonly called No. 3 stone can be added at a small additional cost, or even the use of Portland cement would be warranted by the improved quality of the mixture.

Mr. Farrington states that a fairly coarse, sharp, well-graded sand gives the best results. This probably is true where the traffic is light, but at the same time there should be enough of the fine sand to reduce the percentage of voids to a minimum in order to get density and stability.

In hardening the subgrade, the nearer we approach the stability of concrete, the more satisfactory will be the results, and I believe the day is not far distant when concrete will be extensively used for the base of nearly all road surfaces where there is any considerable amount of traffic. As to a seal coat being applied to the surface, it does not seem to be necessary when the aggregates are properly graded and combined with good asphalt, and the mixture rolled to its maximum density, or at least not more than a squeegee coat should be needed simply to seal the surface and not to act as a wearing course.

TRAFFIC.

Mr. Farrington has covered the subject of traffic pretty thoroughly, and I fully agree with him as regards the success of mixed sand and asphalt surfaces for medium traffic when scientifically combined and properly laid.

SPECIFICATIONS.

The specifications submitted fulfill the requirements pretty thoroughly, but there are a few points which I would like to discuss. It is doubtful if 3 ins. of hardening will be sufficient in all cases, and I should make this requirement more elastic, to meet such conditions as may be encountered. I would also provide for $\frac{1}{2}$ in. of coarse sand being spread on the subgrade, on which the oil shall be applied, and instead of making it a requisite that a definite amount of sand should be spread on each application of oil, I would specify that sand should be applied in thin layers until no surplus of oil appeared on the surface

after rolling. We have found that more sand could be worked into the oil in this manner than when a lot of sand was spread at once.

I would also recommend a lower maximum temperature to which the oil should be heated, say not over 325 degrees fahr., especially if a hot mixer is used, and I would increase the amount of oil used so that the finished pavement would contain from 8 to 10 per cent., depending on the grading of the aggregates.

MR. JOHN S. KEYES * (*by letter*). — I don't know as I have any criticism to make of Mr. Farrington's paper except in the matter of rolling. I do not think it is necessary to use a tandem roller, as satisfactory results have been obtained under my supervision by using an iron hand-roller filled with water weighing about 500 lbs., rolling first lengthwise with the road, care being taken to commence rolling at the gutters so as to preserve the crown of the road, and finally a light horizontal rolling to iron out the surface. We haven't any tandem roller in Concord, so we were obliged to use this method. The sand and gravel are heated and mixed by hand in the pit and delivered on the job at once. The oil used was Standard Oil Binder "B" and Texas Asphalt No. 96 heated to about 300° fahr. The gravel used was clean and sharp, free from loam and clay, not over 15 per cent. being retained on a half-inch mesh and nothing passing a 200 mesh, and was mixed with about twenty gallons of oil to the cubic yard. I do not believe a horse roller is satisfactory on the oil and gravel surface, as the horses' feet pick up more or less material and tend to make depressions which to my mind are difficult to eradicate; however, in my experience a scraper has never been used as described by Mr. Farrington. Our method here is to roll the subgrade very thoroughly and smoothly. I disagree with Mr. Farrington where he says, "In constructing a mixed sand and oil surface, the subgrade is shaped and, if sandy, is hardened with the best material available, usually sandy loam or clay." I should never, if possible to avoid it, use any loam or clay in the subgrade; trouble would be sure to arise under the frost action, and I should expect to find the road breaking up under these conditions. We use cobblestones from the gravel pits for all our

* Chairman, Department of Roads and Bridges, Concord, Mass.

subgrade, filling the voids, after rolling, with coarse gravel, and then rolling to a true grade; over this we spread, while hot, the mixture as described above to a depth of $2\frac{1}{2}$ ins. and roll with hand roller, keeping the traffic off for twenty-four hours. The crown should never be over $\frac{3}{8}$ in. to the foot; in fact, $\frac{1}{4}$ in. to the foot seems preferable; this surface being watertight, small pitch is necessary to shed the water to the gutter. No seal coat is applied till the second year. The cost is thirty-seven cents a square yard above the subgrade.

We have a section of our Main Street which was built in this manner five years ago, with these exceptions; the depth was 4 ins. and the cost, fifty-four cents a square yard. This has never required any repair, and carries a mixed traffic of market wagons and automobiles. The maximum automobile traffic is 1125 an hour on pleasant Sundays and holidays during the summer season. Regarding layer roads, it would be hard to improve Mr. Farrington's method.

MR. W. R. FARRINGTON* (*by letter*). The writer notes, in the discussion on sand and oil roads, that considerable stress is laid on the apparent deficiency of bituminous material in the mixture used on state highway work in Massachusetts, it being stated, by some of those taking part in the discussion, that probably much better results would be obtained by the use of about twice the amount. In this connection the writer would call attention to three points.

First. The percentage of bituminous material used on the state highway work was determined only after two or three years of actual experience. It was found that a less amount would not thoroughly coat the grains, and that an additional amount not only was apparently unnecessary but that it was actually detrimental in that surfaces constructed of such mixtures would not hold their shape and tended to rut and crawl under travel. It seems to be a well-established fact that on asphalt or oil-asphalt work, the best results are obtained by the use of just the amount of bituminous material required to thoroughly coat the grains of sand or larger aggregate, and that the finer and better graded the aggregate, the more bituminous

* Author's closure.

material is required. Tests made of sand used on the state highway work show that the sand or sandy gravel used is deficient in fine grains, according to the sheet asphalt or Topeka specifications. In the opinion of the writer, this explains the fact that additional bituminous material does not give better results. There is no doubt that better graded sand would give better results, as is evidenced by results from the use of cement as mentioned, but the addition of cement or other materials to improve the grading means additional cost.

Second. The sand and oil mixture serves not only as a wearing surface, but also takes the place of the base or foundation, any hardening used on the subgrade being sufficient only to carry the travel during construction, and not adding any material strength to the surface. It is possible that under such conditions a somewhat different mixture is called for than where the mixture serves only as a wearing surface on a good gravel, broken stone or concrete base.

Third. In the sections where the sand and oil roads have been constructed, the conditions do not warrant an expensive surface. With the materials available, to approximate either a sheet asphalt or a Topeka specification mixture means a large cost. Doubling the bituminous material used would alone add from 15 to 20c. per sq. yd. to the cost. However, as stated, if it is found practicable to grade the material for the wearing surface only, it would seem possible to use sand and oil with good results, in other sections where the travel is heavier, and the conditions would warrant the additional cost.

In the opinion of the writer, the reason for the successful results obtained with the sand as found in the ordinary pit and the amount of bituminous material used, is the seal coat, which apparently has been overlooked by some of those taking part in the discussion. As stated, the first mixed roads were not sealed when constructed, and with these a tendency to disintegrate was observed within a year or two. The application of a seal coat stopped this tendency. The seal coat, without doubt, contains a larger proportion of bituminous material, it prevents moisture working into the mixture and it forms a surface which is somewhat resilient but is not of sufficient thickness to rut or

roll under travel. The cost of the seal coat, which adds about $\frac{1}{2}$ in. to the thickness of the surface, is only 6 or 8c. per sq. yd., whereas the addition of 4 or 5 per cent. of bituminous material will increase the cost from 15 to 20c. per sq. yd., and, in the opinion of the writer, additional bituminous material cannot be used advantageously without grading the sand, which means further additional cost.

Relative to Mr. Fletcher's description of the oil and dirt roads in California, the writer would state that the sand and oil layer roads in Massachusetts have acted when constructed much the same, although eventually we have in most cases succeeded, by the addition of sand, etc., in obtaining a mixture which does not rut or roll badly under the travel to which these roads are subjected. It seems well to state also that we have not in any case obtained good results from the use of clayey or loamy soils, although, as stated, the presence of a small proportion of clay or loam is not objectionable, if properly divided and distributed throughout the mass.

Relative to the use of an asphalt plant, bids have in several instances been asked for and received from parties who have had such an equipment, but in all cases the bids have been very high, and all interested have agreed that such a plant could not be used profitably at the prices for which the work is being done with other equipment, as a suitable asphalt plant means not only a large first cost, but a much greater cost for transportation between jobs, than with the equipment now being used.

As to the question of the oil or oil-asphalt being burned, or the grains of sand so coated with light oil from combustion of the crude oil used in the burners that good results cannot be obtained with a mixer so arranged that the flame comes in direct contact with the materials during mixing, the writer, who has had an opportunity to watch most of the state highway sand and oil work in Massachusetts and observe the results on the roads after the surfaces have been subjected to travel for several seasons, fails to see any indication of burning of the bituminous material or sufficient coating of the aggregate to affect the results. This conclusion is also apparently corroborated by the reports of chemists of the Office of Good Roads, and others who

have tested not only the fresh mixtures, but also samples of the mixture taken from surfaces more than three years old.

As to the possibility of thoroughly drying the sand with pipe or arch heaters, the writer, as a result of careful observation, believes that it is possible to obtain as good results with these heaters as with a mechanical heater, provided the sand is properly turned on the heater or shoveled from one heater to another as it should be, but realizes the difficulty of obtaining this result with ordinary labor, and it is principally for this reason that the use of a mechanical heater is advocated, since a careful comparison of the costs does not seem to show much advantage in the latter, taking into consideration the first cost, etc.

Relative to rolling, no difficulty has been experienced in rolling with a tandem roller, on a broken stone or other hard base, a layer of sand and oil 2 ins. thick after rolling, but even with such a base the use of a steam roller is impracticable at first with a sufficient amount of the mixture to give about 4 ins. after rolling. On the other hand, when a horse-roller is used, no difficulty is experienced in removing the inequalities caused by the horse's feet, provided a suitable scraper is used during the rolling.

As to cross rolling, while the writer has no doubt that this is advisable with wider surfaces, it does not seem practicable with a 16 or 18 ft. surface, if the shoulders are too soft to carry the roller, as is usually the case where the sand and oil roads have been constructed. In such cases, cross rolling not only tends to force the surface out of shape, because of the short turns it is necessary to make in rolling, but also results in breaking down the edges.

MEMOIR OF DECEASED MEMBER.

JOHN HERBERT GERRISH.*

Died February 7, 1916.

JOHN HERBERT GERRISH, son of John J. and Susan (Small) Gerrish, was born in Portland, Me., October 13, 1858. He was the eldest of a family of six, three brothers and three sisters.

Mr. Gerrish was educated in the public schools of Portland, and in his first business experience was associated with his father in furnishing railroad supplies. After a few years he entered the employ of the Eastern Dredging Company, and in 1887 came to Boston as the agent of the company, and upon the death of Mr. Wright, the president, Mr. Gerrish became treasurer, which position he retained until he retired from the company in 1913. During this period he was the active head of the company, which was working on many of the larger public works in and around Boston harbor and at other places along the New England coast, among them the deepening and enlarging of the channels and anchorage basin in Boston and other harbors; the Cape Cod Canal, the Charles River Dam, the building up of the South Boston flats and many other works.

Mr. Gerrish was married in 1883 to Ida L. Thurston, of Portland, Me., and had a family of nine children, eight of whom survive him, three boys and five girls.

Mr. Gerrish and his family moved from Portland to West Medford in 1887 and, after a residence there of eleven years, moved to Melrose Highlands, at 20 Farwell Avenue, in 1898, where the family still resides.

Mr. Gerrish was also treasurer of the Gerrish Dredging Company; treasurer of the Boston Mailing Company; member of the Boston Chamber of Commerce, the Boston City Club,

* Memoir prepared by Frank W. Hodgdon and John L. Howard.

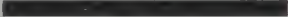
Boston Society of Civil Engineers, Massachusetts Real Estate Exchange, and West Medford Lodge, I. O. O. F.

In his religious life he was a member of the Congregational church and was always actively interested in the church work in the place where he resided.

Mr. Gerrish was a man of unassuming merit, who made many warm friends, and was always ready to give of his time and energy to assist any worthy cause and do his share of the work in all cases.

He was a most domestic man, and devoted to his family and home life.

Mr. Gerrish was elected an Associate of the Boston Society of Civil Engineers on May 18, 1898.



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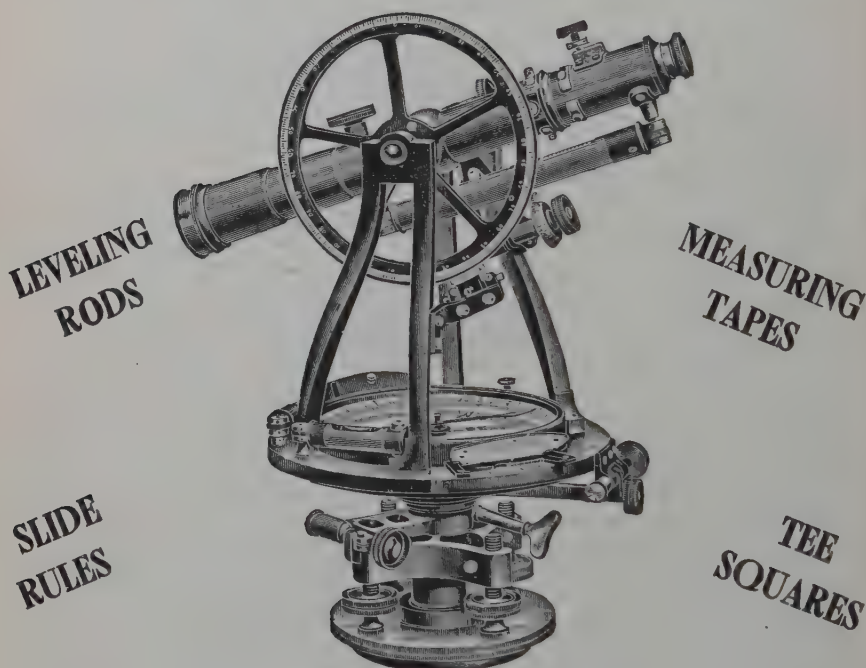
INDEX TO ADVERTISERS.

	PAGE
A. B. SEE ELECTRIC ELEVATORS, 111 Devonshire St., Boston.....	XVI
ABERTHAW CONSTRUCTION Co., 8 Beacon St., Boston.....	XV
ADAMS, H. S., 108 Ames Building, Boston, Mass.....	IV
ASPINWALL & LINCOLN, 3 Hamilton Pl., Boston.....	IV
ASSOCIATED ARCHITECTS PRINTING & SUPPLY Co., 144 Congress St., Boston.....	XVII
BAY STATE DREDGING Co., LTD., 247 Atlantic Ave., Boston....	X
BISHOP, J. W., & Co., 683 Atlantic Ave., Boston.....	XI
BLAIR, ISAAC, & Co., INC., 433 Harrison Ave., Boston.....	XI
BOND, HAROLD L., Co., 383 Atlantic Ave., Boston.....	XIV
BUSS, EDWARD A., 85 Water St., Boston.....	IV
COLEMAN BROS., 1 Marginal St., Chelsea.....	XIV
CONCRETE CONSTRUCTION Co., 28 School St., Boston.....	XI
DETROIT GRAPHITE Co., 94 Milk St., Boston.....	XVII
DIXON CRUCIBLE Co., Jersey City, N. J.....	XVII
EASTERN BRIDGE AND STRUCTURAL Co., Worcester.....	XVI
FAY, SPOFFORD & THORNDIKE, 308 Boylston St., Boston.....	IV
FORT HILL PRESS, 176 High St., Boston.....	XVI
FULLER, GEORGE W., 170 Broadway, New York.....	IV
GOW, THE CHARLES R., Co., 166 Devonshire St., Boston.....	XIII
HALL, JOHN G., & Co., 114 State St., Boston.....	XVII
HARRINGTON, EPHRAIM, 20 Pemberton Sq., Boston.....	IV
HERN, J. L., ENGINEERING Co., 149 Pearl St., Boston.....	IV
HERSEY MFG. Co., South Boston.....	XVIII
HOLBROOK, CABOT & ROLLINS, CORPN., 6 Beacon St., Boston....	VII
HOLZER, U., 25 Bromfield St., Boston.....	X
HUGHES, EDWARD F., 8 Oliver St., Boston.....	XVII
JACKSON, D. C. & WM. B., 248 Boylston St., Boston.....	IV
JONSBERG, F. F., Co., 733 Old South Building, Boston.....	XI
LEDDER & PROBST, 56 Franklin St., Boston.....	XIV
MAIN, CHARLES T., 201 Devonshire St., Boston.....	III
MAKEPEACE, B. L., 12 Bromfield St., Boston.....	II
METCALF & EDDY, 14 Beacon St., Boston.....	IV
MILLER, WILLIAM L., 71 Alford St., Boston.....	VIII
MOSS, CHARLES E. Co., 38 Broad St., Boston.....	XIV
NEW ENGLAND BUREAU OF TESTS, INC., 12 Pearl St., Boston....	V
NEW ENGLAND SAND & GRAVEL Co., West Peabody, Mass.....	VIII
OLD CORNER BOOK STORE, 27 Bromfield St., Boston.....	XVII
PALMER, JOHN E., 1012 Old South Bldg., Boston.....	XVII

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	PAGE
PENNSYLVANIA CEMENT CO., 161 Devonshire St., Boston.....	XI
PERRIN, SEAMANS & CO., 57 Oliver St., Boston.....	XVII
RIDEOUT, CHANDLER & JOYCE, 178 High St., Boston.....	XIV
ROCKPORT GRANITE CO., Rockport, Mass.....	VI
ROURKE & SHERMAN, 6 Beacon St., Boston.....	IV
SIMPSON BROS. CORPN., 166 Devonshire St., Boston.....	VI
SMITH, B. F., & CO., 60 Federal St., Boston.....	XIV
SPAULDING PRINT PAPER CO., 44 Federal St., Boston.....	XIII
STONE & WEBSTER, 147 Milk St., Boston.....	IX
THOMPSON, SANFORD E., 141 Milk St., Boston.....	IV
THOMSON METER CO., 100 Bridge St., New York.....	XV
THORPE, LEWIS D., 201 Devonshire St., Boston.....	IV
TUCKER, EDWARD A., CO., 683 Atlantic Ave., Boston.....	VI
WALDO BROTHERS, Boston.....	X
WARREN BROTHERS CO., 142 Berkeley St., Boston.....	XII
WARREN FOUNDRY AND MACHINE CO., 111 Broadway, New York...	VIII
WESTON, ROBERT SPURR, 14 Beacon St., Boston.....	V
WHEELER, CHARLES D., 65 Kilby St., Boston.....	XIII
WHITMAN & HOWARD, 220 Devonshire St., Boston.....	V
WOOD, R. D., & CO., Philadelphia.....	VIII
WORCESTER, J. R., & CO., 79 Milk St., Boston.....	V

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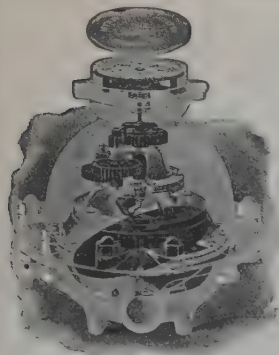
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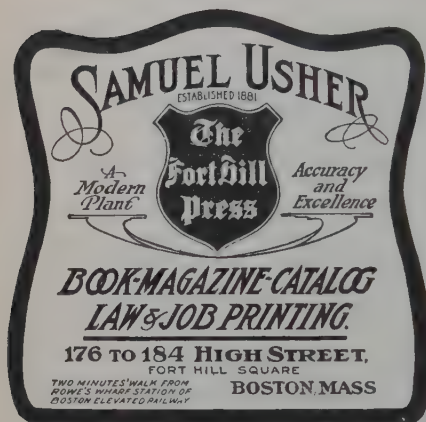
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